EVALUVATION OF ORTHODONTIC TOOTH MOVEMENT IN HUMANS WITH LOW LEVEL LASER THERAPY

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CERTIFICATE

This is to certify that this dissertation titled **"EVALUVATION OF ORTHODONTIC TOOTH MOVEMENT IN HUMANS WITH LOW LEVEL LASER THERAPY"** is a bonafide record of work done by **Dr. ASHWIN SUDHESH** under my guidance during his postgraduate study period between 2010–2013.

This dissertation is submitted to **THE TAMIL NADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the degree of **Master of Dental Surgery in Branch V – Orthodontics and Dentofacial Orthopedics**. It has not been submitted (partially or fully) for the award of any other degree or diploma.

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CONTENTS

ABSTRACT

Introduction – The duration of orthodontic treatment is a major concern for the patients. Many methods to reduce treatment time have been tested in the past each having its own disadvantages. A non invasive method of accelerating tooth movement is needed in order to enhance the rate of tooth movement. Hence the aim of this study was to investigate the effects of low level lasers on orthodontic tooth movement during canine retraction.

Materials and Methods – 13 adult patients were used in the study requiring retraction of maxillary canines as a part of orthodontic treatment. Low level laser therapy applied on the test side. The other side was considered as control. Retraction was initiated on both sides using NiTi coil springs. The rate of tooth movement was evaluated after 2 months.

Results – There was a significant difference in the rate of tooth movement between the lased and non lased side. An average increase of 43% in the rate of tooth movement was observed on the lased side.

Conclusions – Low level laser therapy is an efficient and non invasive method of accelerating tooth movement.

Key words: Canine retraction, Low level laser therapy, White light scanning, Biostimulation

INTRODUCTION

Tooth movement through orthodontics occurs as a result of mechanical forces acting on teeth resulting in a series of biologic responses. Over the years not only orthodontists have had difficulties in treating and finishing a case, but due to the long duration of treatment, patients neglect to go through orthodontic treatment and tend to discontinue it[73].

In general, the period of time required for fixed appliance treatment for orthodontic patients is approximately 2 - 3 years. During this period there is an increased risk of root resorption, gingival inflammation and dental caries[36]. Reducing orthodontic treatment time requires increasing the rate of tooth movement. Over the years, orthodontists have vested interests in reducing the length of orthodontic treatment and hoped to accomplish treatment objectives in timeliest manner possible. In an effort to meet these demands, orthodontists have searched methods to increase the rate of orthodontic tooth movement.

In the past, many studies have been conducted in order to enhance tooth movement. These include the following:

1. Low voltage currents were delivered using a special electric device[12].
2. Intra-oral rare earth magnets[11].

3. Chemical agents like Prostaglandins[70], Osteocalcin[24], Vitamin D[8], Calcitriol[28], Parathyroid hormone which are injected to enhance tooth movement.

4. Corticotomy[31]

5. Distraction osteogenesis[2]

However the above mentioned procedures have distinct disadvantages. These procedures are cumbersome, technique sensitive, cause pain and discomfort to the patients and can be invasive in nature. Hence a non- invasive procedure that was painless and could enhance tooth movement remained a question.

The development of Lasers has been a turning point in the history of science and engineering[43]. It has produced a completely new type of systems with potentials for applications in a wide variety of fields. It was Albert Einstein in 1917 who first explained the theory of stimulated emission which became the basis of Laser. However, it was in late 1940s and fifties that scientists and engineers did extensive work to realize a practical device based on the principle of stimulated emission. Despite the pioneering work of Townes and Prokhorov it was left to Theodore Maiman in 1960 to invent the first Laser using ruby as a lasing medium that was stimulated using high energy flashes of intense light[43].

Low level laser therapy (LLLT) is also known as “soft laser therapy”. The use of LLLT in health care has been documented in the literature for more than three decades and is gaining an increasing acceptance in conventional medical, physiotherapy, dental, and veterinary practice and refers to the "reaction between laser and the irradiated biological tissue" (Baxter, 1994)[63].

The use of LLLT dates back to 1967 when Dr. Endre Mester, a Hungarian physicist, accidentally discovered that a monochromatic laser could help speed up the healing of soft tissue injuries. By the mid 1970's laser therapy gained popularity in Asia, Africa and the Soviet Union. Today LLLT is used worldwide in the field of medicine, dentistry, physical therapy and chiropractics[43].

LLLT has primarily been shown useful in the short-term treatment of acute pain caused by rheumatoid arthritis, osteoarthritis, tendinopathy, and possibly chronic joint disorders. LLLT has also been useful in the treatment of both acute and chronic neck pain[63].

In dentistry it has been used for post extraction and bone healing therapy. It also helps in curing Herpes labialis, periodontitis, aphthous ulcers, mucositis, in case of paresthesia and trigeminal neuralgia[63]. Moreover recently it has been used for treating dentinal hypersensitivity[68].

In Orthodontics, LLLT has found to be proved as an effective tool. It is widely used for the following procedures:

- Esthetic contouring of the gingival scaffold.

- Pain reduction during orthodontic treatment[15]
- Treatment of Temporomandibular disorders[55]
- Rapid bone regeneration after Rapid Maxillary Expansion[6]
- Minor surgical procedures like frenectomy, operculectomy

Although LLLT has been used in orthodontics, its use in accelerating tooth movement is not well documented. Majority of the studies in literature that examined the effect of low-intensity laser therapy on the rate of orthodontic tooth movement were short-term animal studies[29]. Its use for plummeting the treatment duration still remains a debate. Several studies have shown that LLLT promotes bone repair[33]. Therefore, if LLLT can cause an increase in bone remodeling, it may also have an effect on increasing the rate of tooth movement.

Therefore the aim of our study is:

"EVALUVATION OF ORTHODONTIC TOOTH MOVEMENT IN HUMANS WITH LOW LEVEL LASER THERAPY"

REVIEW OF LITERATURE

Reitan et al[27] (1964) stated that the initial force for canine retraction should be light, because this produces biologic effects. These lighter forces will produce less extensive hyalinized tissue that can be readily replaced by cellular elements. He stated that an appropriate force of 150 to 200 gms for maxillary canines should be used for translatory movement.

Burstone et al[7] (1976) stated that Vertical loops or modified vertical loops are basically frictionless springs which are used for canine and anterior tooth retraction. The design and selection of a proper loop or retraction spring should be based on a number of scientific criteria. Foremost among these would be a sufficiently high moment-to-force ratio so that root apices are not displaced mesially or anteriorly. A retraction spring with zero angulation of its horizontal-occlusal arms delivers a moment when activated to produce a force. The ratio of this moment and force is constant throughout the elastic range of activation of the spring. The higher the moment-to-force ratio, the greater is the clinician's control over the apices of the anterior teeth. An analysis of design factors demonstrates that the higher the loop occluso-gingivally, the shorter its horizontal length occlusally, and the greater the gingival horizontal length as in a T loop; these are significant factors in increasing the moment-to-force ratio. The placement of helices is a useful design consideration but the main effect is in reducing the load-deflection rate. By keeping these design factors in mind, the clinician can build into his retraction springs, without the placement of any gable bend, the largest possible moment-to-force ratio so as to optimize his tooth movement.

Davidovitch et al[12] (1980) determined the usefulness of exogenous electric currents in accelerating orthodontic tooth movement and to study the effect of electric-orthodontic treatment on periodontal cyclic nucleotides. Maxillary canines were tipped in five cats by 80 g force. Enhanced bone resorption was observed near the anode (PDL compression site), while bone formation was pronounced near the cathode (PDL tension site). Staining for cyclic nucleotides was increased when electric stimulation was added to the mechanical force. He concluded that orthodontic tooth movement may be accelerated by the use of locally applied electric currents.

Huffman et al[14] (1983) conducted a clinical study to compare the amount and rate of movement and the tipping of canines retracted on 0.016 inch and 0.020 inch round wire with a continuous force of 200 grams and medium-width 0.022 inch by 0.028 inch nonangulated Siamese brackets. On one side canines were retracted on 0.016 inch wire and on the other side of the same arches, on 0.020 inch wire. Over 10 weeks, the mean amount of movement for twenty-one canines on the 0.016 inch wire was 3.37 mm., and for the twenty-one canines on the 0.020 inch wire it was 2.99 mm. The mean rate of movement in twenty-five arches was 1.37 mm. per month on the 0.016 inch wire and 1.20 mm. per month on the 0.020 inch wire. Over a period of 10 weeks, the mean amount of tipping for seventeen canines on the 0.016 inch wire was 5.3 degrees, and for the seventeen canines on the 0.020 inch wire it was 1.7 degrees. Since less tipping occurred on the 0.020 inch wire and the rates of movement were similar, there appears to be an advantage in retracting canines along 0.020 inch round wire rather than on 0.016 inch round wire. It would seem, also, that a greater force is not required to slide a tooth bonded or banded with an 0.022 by 0.028 inch bracket slot along an 0.020 inch round wire than along an 0.016 inch round wire.

Burstone et al[60] (1984) discussed the following points regarding the mechanics of orthodontic tooth movement. He stated that Orthodontic forces can be treated mathematically as vectors. When more than one force is applied to a tooth, the forces can be combined to determine a single overall resultant. Forces can also be divided into components in order to determine effects parallel and perpendicular to the occlusal plane, Frankfort horizontal, or the long axis of the tooth. Forces produce either translation (bodily movement), rotation, or a combination of translation and rotation, depending upon the relationship of the line of action of the force to the center of resistance of the tooth. Since most forces are applied at the bracket, it is necessary to compute equivalent force systems at the center of resistance in order to predict tooth movement.

Yamasaki et al[70] (1984) evaluated the effect of prostaglandin on orthodontic tooth movement. In the first phase, lingual arch springs were applied on both sides of the maxilla to upper first premolars which were scheduled for extraction. One side received submucosal injections of PGE, and the other received vehicle injections. The rate of tooth movement in the buccal direction approximately doubled on the side of several PGE, injections as compared to the control side. In the second phase, the PGE, injections were applied in canine-retraction cases for up to 3 weeks in first-premolar-extraction cases. The rate of distal canine movement was almost double on the side receiving PGE, injections as compared to the vehicle-injected side. In the third phase, the PGE, injections were applied on routine canine retraction in first-premolar-extraction cases. The rate of distal canine movement was almost 1.6 fold on the side of PGE, injections as compared to the vehicle-injected side. Throughout this study, no side effects were observed macroscopically in the gingiva and roentgenographically in the alveolar bone, except for a slight pain reaction consistent with orthodontic tooth movement.

Mester[41] (1985) reviewed the experimental and clinical use of lasers over a 20-year period, during which laser effects on 15 biological systems were studied. Low-energy laser radiation was found to have a stimulating effect on cells, and high-energy radiation had an inhibiting effect. The application of lasers to stimulate wound healing in cases of nonhealing ulcers is recommended.

Collins et al[8] (1988) determined if the rate and amount of orthodontic tooth movement in a sample of cats could be enhanced by the injection of a vitamin D metabolite, 25dihydroxycholecalciferol (1,25D) into the periodontal ligament. After 21 days of canine retraction with a light-wire retraction spring, the teeth that had received weekly intraligamentous injections of a solution of 1,25D in dimethylsulfoxide (DMSO) had moved 60% further than matched control teeth ($P < 0.05$). At the histologic level, increased numbers of mononuclear osteoclasts were recruited and activated, resulting in greater amounts of alveolar bone resorption on the pressure side of the periodontal ligament. No obvious clinical, microscopic, or biochemical side effects were noted.

Enwemeka[17] (1988) in his study about lasers concluded that laser biostimulation is potentially a useful tool in the treatment of wounds, particularly those cutaneous and subcutaneous wounds that are either complicated by infection or inherently require a prolonged period of time to heal. The precise dosage and frequency of treatment required to promote healing even in animal models remain elusive, as is experimental determination of the depth of penetration of lasers.

Peter Ngan et al[44] (1989) determined the perception of discomfort over time by a group of 70 patients undergoing orthodontic treatment. Patients who were selected for comprehensive orthodontic treatment completed questionnaires before insertion of separators and initial arch wires and after placement at 4 hours, 24 hours, and 7 days. The level of discomfort during these time periods was assessed by a visual analogue scale. The results showed a significant increase in the level of discomfort after insertion of either separators or arch wires at 4 hours and 24 hours, but not at 7 days. No significant difference was found in the level of discomfort of patients more than 16 years of age compared with those 16 years and under. No significant difference in discomfort was found between the sexes. These results are useful in relating expectations of discomfort to who undergo orthodontic treatment.

Sandy et al[53] (1993) in his review highlighted the recent developments in bone cell biology. He summarized that osteoblasts are recognized as the cells that control both the resorptive and the formative phases of the remodeling cycle, and receptor studies have shown them to be the target cells for resorptive agents in bone. The osteoblast is perceived as a pivotal cell, controlling many of the responses of bone to stimulation with hormones and mechanical forces. It is apparent that not all the cellular responses induced by mechanically deformed tissues can be explained by the current paradigm emphasizing the importance of prostaglandin production and cAMP elevation; the mobilization of membrane phospholipids giving rise to inositol phosphates offers an alternative second messenger pathway. It is also argued from circumstantial evidence that changes in cell shape produce a range of effects mediated by membrane integral proteins (integrins) and the cytosk'eleton, which may be important in transducing mechanical deformation into a meaningful biologic response.

Darendeliler[11] (1995) determined whether the application of either samarium cobalt magnets or pulsed electromagnetic fields could increase the rate and amount of orthodontic tooth movement observed in guinea pigs. Fifteen grams of laterally directed orthodontic force were applied to move the maxillary central incisors of a sample of 18 young male Hartley guinea pigs divided into three groups: group 1, an orthodontic coil spring was used to move the incisors; group 2, a pair of samarium-cobalt magnets provided the tooth moving force; and group 3, a coil spring was used in combination with a pulsed electromagnetic field. The results showed that both the static magnetic field produced by the samarium-cobalt magnets and the pulsed electromagnetic field used in combination with the coil spring were successful in increasing the rate of tooth movement over that produced by the coil springs alone.

Lim et al[35] (1995) tested the efficacy of LLLT in controlling orthodontic postadjustment pain. Thirty-nine volunteers were selected for this study that used a double-blind design with placebo control. Elastomeric separators were placed at the proximal contacts of one premolar in each quadrant of the dentition to induce orthodontic pain. The tip of a 30 mW gallium-arsenide-aluminium (830 nm) diode laser probe was then placed at the buccal gingiva and directed at the middle third of the root. Three different treatment durations of 15, 30, and 60 seconds and one placebo treatment of 30 seconds were tested within each subject. The study was conducted over 5 days, and the visual analogue scale (VAS) was used to quantify the pain experienced by the subjects before and after laser applications for each day.

The results showed that showed that teeth exposed to laser treatment had lower levels of pain as compared with those with the placebo treatment.

Lotzof et al[38] (1996) compared the time required to retract canine teeth by using two different preadjusted bracket systems (Tip-Edge, TP Orthodontics, LaPorte, Ind., versus A-Company straight wire, Johnson and Johnson, San Diego, Calif.) in a human sample. Anchorage loss as a result of this movement was also evaluated. A sample of 12 patients was randomly selected who required the removal of first premolars in one or both arches as a part of their orthodontic treatment. The rate of retraction and anchorage loss were evaluated. There was no statistically significant difference in the rates. The mean anchorage loss was 1.71 mm for the Tip-Edge bracket, and 2.33 mm for the straight wire bracket. The difference in the amount of anchorage loss was inconclusive as the sample size was too small.

Hasler et al[25] (1997) measured the rate of movement of the maxillary canines into the healed or recent extraction alveolus of the first premolar in 22 patients aged 10-27 years. On one side of the dental arch, the first premolar was extracted. After a median time of 86 days, the contralateral first premolar was extracted and the distalization of both canines started using Gjessing canine retraction springs. The experiment was ended when one of the two canines had been sufficiently distalized. Recordings of the positions of the canines at the beginning of the study, at the start of the distalization and at the end were made from dental casts and standardized intraoral radiographs. The canine on the recent extraction side moved faster than that on the healed side, but also tipped somewhat more.

Walsh et al[68] (1997) The use of LLLT in the treatment of dentinal hypersensitivity and periodontal ligament pain during orthodontic tooth movement has been shown in clinical trials to be both safe and effective. There is accumulating evidence which indicates the potential of lethal laser photosensitization as a technique for the destruction of cariogenic and other microorganisms within the mouth without causing undue thermal stress to the tooth. Improvements in the design of LLLT equipment are necessary to enable these various techniques to be accomplished within an adequate timeframe and without breaching cross infection control requirements. Given the low - technology, low-cost characteristics of LLLT, the future for hard tissue LLLT applications is promising. As with soft tissue applications of LLLT, efforts should be directed toward investigating the precise dosimetry required for therapeutic laser effects, in order to achieve standardization of treatment protocols.

Kobayashi et al[32] (1998) evaluated the effects of local administration of osteocalcin, a major noncollagenous bone matrix protein, on experimental tooth movement in rats. An orthodontic elastic band was inserted between the upper first and second molars, and the first molar was moved mesially. Purified osteocalcin (0 to 10 micrograms) in 20 microliters of phosphate-buffered saline was injected into the region of the root bifurcation of the first molar daily for 4 days. Tooth movement increased significantly following the injections. Histological studies revealed that the injections markedly stimulated the appearance of osteoclasts on the pressured side of the alveolar bone surface. The results suggest that osteocalcin has an additive effect on the rate of orthodontic tooth movement through the enhancement of osteoclastogenesis on the pressured side.

Kawasaki et al[29] (2000) evaluated the effect of tooth movement in rats.A total of 10 g of orthodontic force was applied to rat molars to cause experimental tooth movement. A Ga-Al-As diode laser was used to irradiate the area around the moved tooth, and after 12 days, the amount of tooth movement was measured. Calcein was injected subcutaneously to label the newly formed alveolar bone for quantitative analysis. Immunohistochemical staining of proliferating cell nuclear antigen was performed to evaluate cellular proliferation. TRAPase staining was also performed to facilitate the identification of osteoclasts. He concluded that these findings suggest that low-energy laser irradiation can accelerate tooth movement accompanied with alveolar bone remodeling.

Coombe et al[9] (2001) investigated the effects of low level laser irradiation on the human osteosarcoma cell line, SAOS-2. The cells were irradiated as a single or daily dose for up to 10 days with a GaAlAs continuous wave diode laser (830 nm, net output of 90 mW, energy levels of 0.3, 0.5, 1, 2, and 4 Joules). Cell viability was not affected by laser irradiation, with the viability being greater than 90% for all experimental groups. Cellular proliferation or activation was not found to be significantly affected by any of the energy levels and varying exposure regimes investigated. No significant early or late effects of laser irradiation on protein expression and alkaline phosphatase activity were found. Investigation of intracellular calcium concentration revealed a tendency of a transient positive change after irradiation. He concluded that Low level laser irradiation was unable to stimulate the osteosarcoma cells utilized for this research at a gross cell population level.

Hashimoto et al[24] (2001) evaluated the effect of local administration of osteocalcin (OC) on experimental tooth movement in rats. The maxillary first molar was first moved mesially with an initial tipping force of 30 g with a closed-coil spring anchored to the incisor for 10 days (n = 48). Three experimental groups (n = 8) were injected with purified rat OC at doses of 0.1, 1, and 10 micrograms, respectively. The injection into the palatal bifurcation site of the first molar was repeated daily. The control groups (n = 8) were injected with rat serum albumin (10 micrograms), phosphate buffered saline (PBS), or were not injected. Tooth movement was evaluated daily by measuring the inter-cuspal distance between the first and the second molars on a precise plaster model. A significantly larger number of osteoclasts accumulated on the mesial alveolar bone surface in the 1-microgram OC-injected group on day 3 than that observed in control group. These results suggest that administration of OC accelerates orthodontic tooth movement due to enhancement of osteoclastogenesis on the pressure side, primarily in the early experimental period.

Koutna et al[33] (2003) investigated the effect of low-power laser irradiation on the proliferation activity of HeLa cells. The cells were irradiated by a 830 nm semiconductor BTL-10 laser in a continuous or pulsed mode at an energy density ranging from 2 to 99 J/cm2 (power output, 72 to 360 mW). The irradiated cells were incubated and their proliferation activity was assessed by the MTT (3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide) assay at 24, 48, 72 and 96 h. In comparison with the control populations, the irradiated cells showed a significant increase in proliferation, regardless of the energy density used, at 72 and 96 h but not at 24 and 48 h. In addition, the stimulation of proliferation was related to the mode of irradiation. The cells irradiated in the pulsed mode (5 000 Hz) showed a higher proliferation activity than the cells treated by continuous laser light. It is concluded that low-power lasers stimulate HeLa cell proliferation.

Pugliese et al[48] (2003) evaluated the influence of low-level laser therapy on biomodulation of collagen and elastic fibers. Cutaneous wounds were performed on the back of 72 Wistar rats and a Ga-Al-As low-level laser was punctually applied with different energy densities. The animals were killed after 24, 48, 72 hours and 5, 7 and 14 days. In this study, the authors concluded that low-level laser therapy contributed to a larger expression of collagen and elastic fibers during the early phases of the wound healing process.

Nicola et al[45] (2003) studied the activity in bone cells after LLLT close to the site of the bone injury. The femurs of 48 rats were perforated (24 in the irradiated group and 24 in the control group) and the irradiated group was treated with a GaAlAs laser of 660 nm, 10J/cm2 of radiant exposure on the 2nd, 4th, 6th and 8th days after surgery (DAS). Histomorphometric analysis of the bone was carried out. They found that activity was higher in the irradiated group than in the control group. They concluded that LLLT increases the activity in bone cells (resorption and formation) around the site of the repair without changing the bone structure.

Cruz et al[10] (2004) investigated the orthodontic movement velocity in human. Eleven patients were recruited for this 2-month study. One half of the upper arcade was considered control group (CG) and received mechanical activation of the canine teeth every 30 days. The opposite half received the same mechanical activation and was also irradiated with a diode laser emitting light at 780 nm, during 10 seconds at 20 mW, 5 J/cm2, on 4 days of each month. All patients showed significant higher acceleration of the retraction of canines on the side treated with LILT when compared to the control. His findings suggested that LILT does accelerate human teeth movement and could therefore considerably shorten the whole treatment duration.

Sun et al[63] (2004) stated that low-level laser therapy (LLLT) is a newly developing technique in dentistry, although it has been used among medical, dental, physiotherapy, and veterinary professions in some parts of the world for decades. LLLT can offer tremendous therapeutic benefits to patients, such as accelerated wound healing and pain relief. A thorough knowledge about the mechanisms, recognition of the therapeutic window, and how to properly use these cellular phenomena to reach the treatment goals is required.

Kawakami[28] et al (2004) evaluated the effect of 1,25-dihydroxyvitamin D3 (1,25(OH)2D3) on alveolar bone formation during tooth movement in rats. Orthodontic elastics were inserted between the maxillary first and second molars on bilateral sides in male rats. 1,25(OH)2D3 was injected locally, at the concentration of 10(-10) M, once every 3 days in the submucosal palatal area of the root bifurcation of the molar on the right side. Histomorphometric analysis revealed that tooth movement without application of 1,25(OH)2D3 decreased the mineral appositional rate (MAR) on the compression area at 7 days. Repeated injections of 1,25(OH)2D3 in the orthodontically treated animals distinctly stimulated alveolar bone formation on the mesial side at 14 days. He concluded that local application of 1,25(OH)2D3 enhances the reestablishment of supporting tissue, especially alveolar bone of teeth, after orthodontic treatment.

Stein et al[61] (2005) investigated the effect of low-level laser irradiation on proliferation and differentiation of a human osteoblast cell line. Cultured osteoblast cells were irradiated using He-Ne laser irradiation (632 nm; 10 mW power output). On the second and third day after seeding the osteoblasts were exposed to laser irradiation. The effect of irradiation on osteoblast proliferation was quantified by cell count and colorimetric MTT (dimethylthiazol tetrazolium bromide) assay 24 and 48 h after second irradiation. The results showed a significant 31–58% increase in cell survival (MTT assay) and higher cell count in the once-irradiated as compared to nonirradiated cells was monitored. They concluded that LLLT promotes proliferation and maturation of human osteoblasts in vitro. These results may have clinical implications.

`Goulart[22] et al (2006) evaluated the effect of gallinium-aluminium-arsenic (GaAlAs) laser irradiation on the speed of orthodontic movement in canine premolars. Eighteen dogs were divided into two groups, and their third molars were extracted. An orthodontic device was placed between the first molar and the second premolar for stabilization purpose. Group I was irradiated with a dosage of 5.25 J/cm(2) on the right side, whereas the left side was used as the control group. Group II was submitted to the same procedure, but was irradiated with a dosage of 35.0 J/cm(2). Irradiations were done every 7 days, for a total of nine irradiations. The orthodontic space was measured every 21 days. The results showed that the 5.25 J/cm(2) dosage accelerated orthodontic movement during the first observation period, from 0 to 21 days ($p < 0.05$), whereas the 35.0 J/cm(2) dosage retarded the orthodontic movement in the treated group when compared with the control group, during both the first and second observation periods, from 0 to 42 days ($p < 0.05$). He concluded that photoradiation may accelerate orthodontic movement at a dosage of 5.25 J/cm(2), whereas a higher dosage, 35.0 J/cm(2), may retard it.

Turhani[67] et al (2006) analyzed the effect of single low-level laser therapy (LLLT) irradiation on pain perception in patients having fixed appliance treatment. Seventy-six patients (46 women, 30 men; mean age, 23.1 years) enrolled in this single-blind study were assigned to 2 groups. The patients in group 1 (G1; 38 patients, 13 men, 25 women; mean age, 25.1 years) received a single course of LLLT (Mini Laser 2075, Helbo Photodynamic Systems GmbH & Co KG, Linz, Austria; wavelength 670 nm, power output 75 mW) for 30 seconds per banded tooth. The patients in group 2 (G2; 38 patients, 17 men, 21 women; mean age, 21.0 years) received placebo laser therapy without active laser irradiation. Pain perception was evaluated at 6, 30, and 54 hours after LLLT by self-rating with a standardized questionnaire. Major differences in pain perception were found between the 2 groups. He concluded that LLLT immediately after multibanding reduced the prevalence of pain perception at 6 and 30 hours. LLLT might have positive effects in orthodontic patients not only immediately after multibanding, but also for preventing pain during treatment.

Hamblin[43] et al (2006) stated that despite many reports of positive findings from experiments conducted in vitro, in animal models and in randomized controlled clinical trials, LLLT remains controversial. This likely is due to two main reasons; firstly the biochemical mechanisms underlying the positive effects are incompletely understood, and secondly the complexity of rationally choosing amongst a large number of illumination parameters such as wavelength, fluence, power density, pulse structure and treatment timing has led to the publication of a number of negative studies as well as many positive ones.

Lotzof et al[38] (2006) compared the time required to retract canine teeth by using two different preadjusted bracket systems (Tip-Edge, TP Orthodontics, LaPorte, Ind., versus A-Company straight wire, Johnson and Johnson, San Diego, Calif.) in a human sample. Anchorage loss as a result of this movement was also evaluated. A sample of 12 patients was randomly selected from the new patient pool at the postgraduate orthodontic clinic of Montefiore Medical Center. All patients required the removal of first premolars in one or both arches as a part of their orthodontic treatment. The rate of retraction and anchorage loss were evaluated. The mean rates of retraction were 1.88 mm per 3-week period and 1.63 mm per 3-week period for the Tip-Edge and A-Company brackets, respectively. There was no statistically significant difference in the rates (/9 > 0.05). The mean anchorage loss was 1.71 mm for the Tip-Edge bracket, and 2.33 mm for the straight wire bracket. The difference in the amount of anchorage loss was inconclusive as the sample size was too small (power was 10%).

Kanzaki et al[23] (2006) tested the hypothesis that local RANKL gene transfer into the periodontal tissue would accelerate tooth movement. The upper first molars of 6-week-old male Wistar rats were moved palatally using fixed orthodontic wires. The inactivated hemagglutinating-virus of Japan (HVJ) envelope vector containing the mouse RANKL expression plasmid was injected periodically into the palatal periodontal tissue of the upper first molars during TM. Local RANKL gene transfer significantly enhanced RANKL expression and osteoclastogenesis in periodontal tissue without any systemic effects. Local RANKL gene transfer might be a useful tool not only for shortening orthodontic treatment, but also for moving ankylosed teeth where teeth, fuse to the surrounding bone.

Limpanichkul et al[36] (2006) tested the hypothesis that mechanical forces combined with low-level laser therapy stimulate the rate of orthodontic tooth movement. It was a double blind, randomized placebo/control matched pairs clinical trial to test the efficacy of GaAlAs low-level laser therapy (LLLT) on 12 young adult patients who required retraction of maxillary canines into first premolar extraction spaces using tension coil springs with fixed edgewise appliance. LLLT was applied on the mucosa buccally, distally and palatally to the canine on the test side and using a pseudo-application on the placebo side. Dental impressions and casts were made at the commencement of the trial and at the end of the first, second and third months after starting the trial. Measurement of tooth movements was made on each stage model using a stereo microscope. He concluded that there was no significant difference of means of the canine distal movement between the LLLT side and the placebo side for any time periods. The energy density of LLLT (GaAlAs) at the surface level in this study (25 J/cm(2)) was probably too low to express either stimulatory effect or inhibitory effect on the rate of orthodontic tooth movement.

Saito et al[52] (2007) investigated the effects of low-power laser irradiation on bone regeneration during expansion of a midpalatal suture in rats. Gallium-aluminum-arsenide diode laser 100 mW irradiation was applied to the midpalatal suture during expansion carried out over 7 days (3 or 10 minutes per day), 3 days (7 minutes per day for day 0-2 or 4-6), and 1 day (21 uninterrupted minutes on day 0). The bone regeneration in the midpalatal suture estimated by histomorphometric method in the 7-day irradiation group showed significant acceleration at 1.2- to 1.4-fold compared with that in the nonirradiated rats, and this increased rate was irradiation dose-dependent. Irradiation during the early period of expansion (days 0 to 2) was most effective, whereas neither the later period (days 4 to 6) nor the one-time irradiation had any effect on bone regeneration. He concluded that low-power laser irradiation can accelerate bone regeneration in a midpalatal suture during rapid palatal expansion and that this effect is dependent not only on the total laser irradiation dosage but also on the timing and frequency of irradiation.

Seifi et al[54] (2007) investigated the quantitative effects of a pulsed 850 nm laser (Optodan) and a continuous 630 nm laser (KLO3) on the orthodontic tooth movement in rabbits. 18 male albino rabbits divided into three equal groups of control, Optodan and KLO3 were used in this study. In all the groups, NiTi-closed coil springs were used on the first mandibular molars with 4-oz tension. The control group was not irradiated by laser, but the teeth in the laser groups were irradiated 9 days according to the periodontal therapeutic protocols. After 16 days, samples were sacrificed. The distance between the distal surface of the first molar and the mesial surface of the second molar was measured with 0.05-mm accuracy. The mean orthodontic tooth movements of the first mandibular molars were 1.7 +/- 0.16 mm in control group, 0.69 +/- 0.16 mm in Optodan group and 0.86 +/- 0.13 mm in KLO3 group. It could not be concluded that any low-level laser will reduce the speed of teeth movement in orthodontic treatments, and further studies with less or more energies may show different results.

Slattery[59] (2008) highlighted the theories that had been postulated with regards to the mechanism of low level laser therapy. The common theories are Bioluminescence theory, Cellular oscillation theory Biological field theory. All three theories share the basic premise that laser causes activation in the cell, which in turn leads to an intensification of the biochemical processes. It is within this context that the Arndt-Schutz law becomes important with respect to low power laser application. This biological law states that "weak stimuli excite physiological activity, moderately strong ones favor it, strong ones retard it and very strong ones arrest it."

Kravitz et al[34] (2008) stated that soft-tissue lasers have numerous applications in orthodontics, including gingivectomy, frenectomy, operculectomy, papilla flattening, uncovering temporary anchorage devices, ablation of aphthous ulcerations, exposure of impacted teeth, and even tooth whitening. As an adjunctive procedure, laser surgery has helped many orthodontists to enhance the design of a patient's smile and improve treatment efficacy. Before incorporating soft-tissue lasers into clinical practice, the clinician must fully understand the basic science, safety protocol, and risks associated with them.

Pinheiro et al[47] (2008) reported the effect of LLLT on bone healing. The amount of newly formed bone after 830nm laser irradiation of surgical wounds created in the femur of rats was evaluated morphometricaly. Forty Wistar rats were divided into four groups: group A (12 sessions, 4.8J/cm2 per session, 28 days); group C (three sessions, 4.8J/cm2 per session, seven days). Groups B and D acted as non-irradiated controls. Forty-eight hours after the surgery, the defects of the laser groups were irradiated transcutaneously with a CW 40mW 830nm diode laser, (f~1mm) with a total dose of 4.8J/cm2. Irradiation was performed three times a week. Computerized morphometry showed a significant difference between the areas of mineralized bone in groups C and D (p=0.017). There was no significant difference between groups A and B (28 days) (p=0.383). In a second investigation, the effects of LLLT on bone healing after the insertion of implants were determined. Better bone healing after irradiation with the 830nm diode laser were shown from the SEM study, suggesting that, under experimental conditions of the investigation, LLLT at 830nm significantly improves bone healing at early stages. and may increase bone repair at early stages of healing.

Youssef et al[73] (2008) evaluated the effect of the low-level (GaAlAs) diode laser (809 nm, 100 mW) on the canine retraction during an orthodontic movement and to assess pain level during this treatment. A group of 15 adult patients with age ranging from 14 to 23 years attended the orthodontic department for whom the treatment plan included extraction of the upper and lower first premolars because there was not enough space for a complete alignment or presence of biprotrusion. For each patient, this diagnosis was based on a standard orthodontic documentation with photographs, model casts, cephalometric, panorama, and superior premolar periapical radiographies. The orthodontic treatment was initiated 14 days after the premolar extraction with a standard 18 slot edgewise brackets [Rocky Mountain Company (RMO)]. The canine retraction was accomplished by using prefabricated Ricketts springs (RMO), in both upper and lower jaws. The right side of the upper and lower jaw was chosen to be irradiated with the laser, whereas the left side was considered the control without laser irradiation. The laser was applied with 0-, 3-, 7- and 14-day intervals. The retraction spring was reactivated on day 21 for all sides. The amount of canine retraction was measured at this stage with a digital electronic caliper (Myoto, Japan) and compared each side of the relative jaw (i.e., upper left canine with upper right canine and lower left canine with lower right canine). The pain level was prompted by a patient questionnaire. The velocity of canine movement was significantly greater in the lased group than in the control group. The pain intensity was also at lower level in the lased group than in the control group throughout the retraction period. Our findings suggest that low-level laser therapy can highly accelerate tooth movement during orthodontic treatment and can also effectively reduce pain level.

Khaled et al[30] (2008) developed a new method for three dimensional 3D imagining of the dental cast and evaluated it's accuracy in analyzing the different tooth movements. Each subject was clinically examined, and an orthodontic diagnostic study cast was recorded. A 3D computer program was specially designed for more accurate evaluation of the dental effects induced by the three types of maxillary expanders, for the rotation and extrusion. The reliability of generating 3D dental images using dental casts for 3D tooth movement analysis has a great research potential in orthodontics because of its ability to yield accurate and reproducible data.

Stein et al[62] (2008) investigated the initial effect of low-level laser therapy on growth and differentiation of human osteoblast-like cells. SaOS-2 cells were irradiated with laser doses of 1 J/cm2 and 2 J/cm2 using a diode laser with 670 nm wave length and an output power of 400 mW. Untreated cells were used as controls. At 24 h, 48 h and 72 h post irradiation, cells were collected and assayed for viability of attached cells and alkaline phosphatase specific activity. In addition, mRNA expression levels of osteopontin and collagen type I were assessed using semi-quantitative RT-PCR. These results indicate that low-level laser therapy has a biostimulatory effect on human osteoblast-like cells during the first 72 h after irradiation. Further studies are needed to determine the potential of low-level laser therapy as new treatment concept in bone regeneration.

Fujiyama et al[19] (2008) tested the hypothesis that there is no difference in the pain associated with orthodontic force application after the application of local CO_2 laser irradiation to the teeth involved. Separation modules were placed at the distal contacts of the maxillary first molars in 90 patients in this single-blinded study. In 60 of these patients (42 females and 18 males; mean age _ 19.22 years) this was immediately followed by laser therapy. The other 30 patients (18 females and 12 males; mean age _ 18.8 years) did not receive active laser irradiation. Patients were then instructed to rate their levels of pain on a visual analog scale over time, and the amount of tooth movement was analyzed. Significant pain reductions were observed with laser treatment from immediately after insertion of separators through day 4, but no differences from the nonirradiated control side were noted thereafter.

No significant difference was noted in the amount of tooth movement between the irradiated and nonirradiated group. He concluded that the hypothesis was rejected. The results suggest that local CO2 laser irradiation will reduce pain associated with orthodontic force application without interfering with the tooth movement.

Barlow et al[4] (2008) conducted ten prospective clinical trials to compare the rates of closure under different variables and focusing only on sliding mechanics. Of these ten trials on rate of closure, two compared arch wire variables, seven compared material variables used to apply force, and one examined bracket variables. Other articles which were not prospective clinical trials on sliding mechanics, but containing relevant information were examined and included as background information. He concluded that nickel-titanium coil springs produce a more consistent force and a faster rate of closure when compared with active ligatures as a method of force delivery to close extraction space along a continuous arch wire; however, elastomeric chain produces similar rates of closure when compared with nickel-titanium springs.

Shpack et al[58] (2008) compared tipping mechanics (TM) and bodily mechanics (BM) with respect to duration, angulation, and anchorage loss during canine retraction. TM and BM brackets were bonded to the upper right and left canines, respectively, of 14 subjects requiring maxillary first premolar extractions. The upper canines were retracted with variable nickel titanium closed coil springs (F = 0.50 or 0.75 N) attached posteriorly to a Nance anchorage appliance through the first molars. Panoramic radiographs and dental casts were taken at five time points. Canine angulation was assessed with custom metallic jigs inserted into the vertical slots of the canine brackets prior to radiographic exposure. Anchorage loss, as assessed by mesial molar movement, was 1.2 +/- 0.3 mm and 1.4 +/- 0.5 mm for the TM and BM groups, respectively. The results showed that bodily canine retraction occurred faster (38 days) than tipping due to a shorter duration of root uprighting. Anchorage loss (17%-20%) was similar for both retraction methods, ie, maximum anchorage could not be provided by the Nance appliance. Both TM and BM brackets had inadequate rotational control of the retracted canine.

Ross et al[50] (2009) conducted a clinical review and with aq series of case reports on the photobiomodulation effect of lasers. She stated that Photobiomodulation (PBM), also commonly referred to as low-level laser therapy (LLLT) or cold laser therapy uses light energy to elicit biological responses from the cell and normalize cell function. She concluded that Although low-level lasers are being used successfully in many dental clinics, the wide range of applications is still largely unknown to many practitioners, especially dental specialists. In these fields, there is the potential to see the most definitive results of what laser therapy can do to improve clinical outcomes and patient satisfaction.

Kim et al[31] (2009) et al investigate the combined effects of Corticision and LLLT on the tooth movement rate and paradental remodeling in beagles. The maxillary second premolars (*n* = 24) of 12 beagles were randomly divided into four groups (*n* = 6 per group) based on the treatment modality: group A, only orthodontic force (control); group B, orthodontic force plus Corticision; group C, orthodontic force plus LLLT; group D, orthodontic force plus Corticision and LLLT. Ratios of second premolar-to-canine movement were greater by 2.23-fold in group B and 2.08-fold in group C, but 0.52-fold lesser in group D than in group A. In group D, the labeling lines on lamina dura were thin and discontinuous, but intratrabecular remodeling and lamellation were found to be active. He concluded that periodic LLLT after Corticision around a moving tooth decreased the tooth movement rate and alveolar remodeling activity.

Tortamano[65] et al (2009) evaluated the effect of low-level laser therapy (LLLT) as a method of reducing pain reported by patients after placement of their first orthodontic archwires. The sample comprised 60 orthodontic patients (ages, 12-18 years; mean, 15.9 years). All patients had fixed orthodontic appliances placed in 1 dental arch (maxillary or mandibular), received the first archwire, and were then randomly assigned to the experimental (laser), placebo, or control group. This was a double-blind study. LLLT was started in the experimental group immediately after placement of the first archwire. Each tooth received a dose of 2.5 J per square centimeter on each side (buccal and lingual). The placebo group had the laser probe positioned into the mouth at the same areas overlying the dental root and could hear a sound every 10 seconds. The control group had no laser intervention. There was no significant difference in pain symptomatology in the maxillary or mandibular arches in an evaluated parameter. He concluded that LLLT efficiently controls pain caused by the first archwire.

Seiryu et al[57] (2010) hypothesized that CO_2 laser irradiation may reduce the early responses to nociceptive stimuli during tooth movement. The distribution of Fos-immunoreactive (Fos-IR) neurons in the medullary dorsal horn of rats was evaluated. Two hrs after tooth movement, Fos-IR neurons in the ipsilateral part of the medullary dorsal horn increased significantly. CO(2) laser irradiation to the gingiva just after tooth movement caused a significant decrease of Fos-IR neurons. PGP 9.5- and CGRP-positive nerve fibers were observed in the PDL of all study groups. The maximum temperature below the mucosa during CO(2) laser irradiation was less than 40 degrees C. It was suggested that CO(2) laser irradiation reduced the early responses to nociceptive stimuli during tooth movement and might not have adverse effects on periodontal tissue.

Ramia et al[1] (2010) described the microscopic pulpal reactions resulting from orthodontically induced tooth movement associated with low-level laser therapy (LLLT) in rats. Forty-five young male Wistar rats were randomly assigned to three groups. In group I (n _ 20), the maxillary right first molars were submitted to orthodontic movement with placement of a coil spring. In group II (n _ 20), the teeth were submitted to orthodontic movement plus LLLT at 4 seconds per point (buccal, palatal, and mesial) with a GaAlAs diode laser source (830 nm, 100 mW, 18 J/cm2). Group III (n _ 5) served as a control (no orthodontic movement or LLLT). Groups I and II were divided into four subgroups according to the time elapsed between the start of tooth movement and sacrifice (12 hours, 24 hours, 3 days, and 7 days). Up until the 3-day period, the specimens in group I presented a thicker odontoblastic layer, no cell-free zone of Weil, pulp core with differentiated mesenchymal and defense cells, and a high concentration of blood vessels. In group II, at the 12- and 24-hour time points, the odontoblastic layer was disorganized and the cell-free zone of Weil was absent, presenting undifferentiated cells, intensive vascularization with congested capillaries, and scarce defense cells in the cell-rich zone. In groups I and II, pulpal responses to the stimuli were more intense in the area underneath the region of application of the force or force/laser. The orthodontic-induced tooth movement and LLLT association showed reversible hyperemia as a tissue response to the stimulus. LLLT leads to a faster repair of the pulpal tissue due to orthodontic movement.

Gama et al[51] (2010) investigated the influence of low-power laser on tooth movement in rats. Tooth movement is closely related to the process of bone remodeling. The biologic result, with the application of a force to the tooth, is bone absorption on the pressure side and neoformation on the traction side of the alveolar bone. Thirty young-adult male Wistar rats weighing between 250 and 300 g were divided into two groups, control and experimental, containing 15 animals each. The animals received orthodontic devices calibrated to release a force of 40 g/F, with the purpose of moving the first upper molar mesially. Low-intensity laser, wavelength 790 nm, was used in the experimental group; the dose was 4.5 J/cm^2 per point, mesial and distal, on the palatal side, 11 J/cm^2 on the buccal side, and this procedure was repeated every 48 h, totaling nine applications. The active movement was clinically evaluated after 7, 13, and 19 days. He concluded that laser phototherapy, with the parameters in the present study, did not significantly increase the amount of tooth displacement during induced orthodontic movement in rodents.

Yamaguchi et al[69] (2010) designed a study to examine the effects of low-energy laser irradiation on the expression of MMP-9, cathepsin K, and alpha(v)beta3 integrin during experimental tooth movement. Fifty male, 6-week-old Wistar strain rats were used in the experiment. A total force of 10g was applied to the rat molars to induce tooth movement. A Ga-Al-As diode laser was used to irradiate the area around the moving tooth and, after 7 days, the amount of tooth movement was measured. To determine the amount of tooth movement, plaster models of the maxillae were made using a silicone impression material before (day 0) and after tooth movement (days 1, 2, 3, 4, and 7). The models were scanned using a contact-type three-dimensional

(3-D) measurement apparatus. He concluded that that low-energy laser irradiation facilitates the velocity of tooth movement and MMP-9, cathepsin K, and integrin subunits of alpha(v)beta3 expression in rats.

Marquezan et al[40] (2010) determined the effect of two low-intensity laser therapy (LILT) protocols on macroscopic and microscopic parameters of experimental tooth movement. To induce experimental tooth movement in rats, 40 cN of orthodontic force was applied to the left first molars. Next, a gallium-aluminum-arsenide (Ga-Al-As) diode laser with a wavelength of 830 nm and power output of 100?mW was applied with fluence of 6000?J/cm(2) on the area around the moved tooth. Two different application protocols were used in the experimental groups: one with daily irradiation and another with irradiation during early stages. The amount of tooth movement was measured with a caliper, and tartrate-resistant acid phosphatase and picrosirius staining were used to enable identification of osteoclasts and immature collagen, respectively. He concluded that the tested LILT protocols were unable to accelerate tooth movement. Even though the number of osteoclasts increased when LILT was applied daily, the repair at the tension zone was inhibited.

Domniguez et al[13] (2010) studied the effect of therapeutic laser on the time required to complete a corrective non extraction orthodontic treatment in patients with crowding. 60 consecutive patients with more than 5mm crowding, age between 20 and 30 year old, were the initial sample. The first group of 30 was the experimental group C-NE-LA (crowding-Non extraction-

Laser) and the following 30 patients were the control group C-NE-NL (Crowding -Non extraction-No Laser).The final sample was reduced to 23 in the experimental group and 22 in the control group. The experimental group was irradiated with Photon Lase III (AS-GA-Ir) at a wavelength of 830 nm, energy 80 J for 22 seconds along the dental vestibular surface and 22 seconds along the palatal surface of the teeth, 24 hours after the first control and then at any appointment. The control group received identical treatment appliances but was not laser irradiated. The outcome variable was: days to complete the treatment. He concluded that low intensity laser applied during the orthodontic treatment to correct dental crowding, under the protocol here described, accelerated the dental movement, reducing in 30% the average time of treatment.

Burrow[5] (2010) compared the rates of retraction down an archwire of maxillary canine teeth when bracketed with a self-ligating bracket was used on one side and a conventional bracket on the other. In 43 patients requiring maxillary premolar extraction, a self-ligating bracket (Damon3, SmartClip) was used on the maxillary canine on one side and a conventional bracket (Victory Series) on the other. The teeth were retracted down a 0.018-inch stainless steel archwire, using a medium Sentalloy retraction spring (150 g). The mean movement per 28 days for the conventional bracket was 1.17 mm. For the Damon bracket it was 0.9 mm and for the SmartClip bracket it was 1.10 mm. The differences between the conventional and self-ligating brackets were statistically significant. They concluded that The retraction rate is faster with the conventional bracket, probably because of the narrower bracket width of the self-ligating brackets.

Oliveira et al[46] (2010) reviewed the historical perspective of alveolar corticotomies, presenting and illustrating with clinical cases its main indications and finally discussing the biological reasons underlying its use. Although corticotomies are primarily indicated to shorten orthodontic treatment time, we believe that the more rational indications for ACS are for cases where either skeletal anchorage devices cannot be used, or both (ACS and anchorage devices) can be used in combination. The biological stimulus generated by corticotomies is reflected in the structure of trabecular bone, which provides an opportunity to enhance certain orthodontic movements.

Gorur et al[21] (2010) evaluated the effect of low-level laser therapy on traumatized permanent teeth with extrusive luxation in an orthodontic patient. The treatment and follow-up evaluation of two orally luxated maxillary permanent central incisors in a 19-year-old man is described. Detailed anamnesis was taken, and extraoral, intraoral, radiographic examinations and electrical and thermal pulpal tests were performed to determine the type of the luxation and the further treatment protocol. Teeth were splinted with composite resin, and antibiotic therapy was prescribed. Low-level laser therapy was applied for 25 sessions. No root canal treatment was applied to the teeth. Continuation of the orthodontic treatment was restarted after 6 months. No sign of clinical or radiographic pathology was detected after 2 years from the end of the treatment. Teeth were identified healthy and sound without any root canal intervention. Treatments with low-level laser applications may be evaluated as noninvasive alternative treatment options in comparison with endodontic treatment for teeth with extrusive luxation more than 2 mm, especially for those who have orthodontic treatment needs.

Yordanova et al[72] (2011) discussed an alternative surgical approach for laser-assisted uncovering of ectopically impacted canines for orthodontic reasons. She concluded that Er:YAG laser is a revolutionary technology providing alternatives for orthodontists in solving different problems in their everyday practice. It is effective and comfortable modality to reduce treatment time and to promote excellent clinical results.

Sousa et al[39] (2011) evaluated the effect of low-level laser irradiation on the speed of orthodontic tooth movement of canines submitted to initial retraction. Twenty-six canines were retracted by using NiTi spring (force of 150 g/side). Thirteen of those were irradiated with diode laser (780 nm, 20 mW, 10 sec, 5 J/cm^2) for 3 days, and the other 13 were not irradiated and thus were considered the control group. Patients were followed up for 4 months, and nine laser applications were performed (three each month). The movement of the canines was evaluated through 3D casts. Periapical radiographs of the studied teeth were submitted to Levander, Malmgreen, and alveolar bone ridge analyses to evaluate tissue integrity. He concluded that the diode laser used within the protocol guidelines increased the speed of tooth movement. This might reduce orthodontic treatment time.

Akhare et al[2] (2011) studied the effects of dentoalveolar distraction on the dentofacial structures. The study sample consisted of 20 maxillary canines in 10 growing or adult subjects (mean age, 16.53 years; range, 13.08-25.67 years). First premolars were extracted, the dentoalveolar distraction surgical procedure performed, and a custom-made intraoral, rigid, tooth-borne distraction device was placed. The canines were moved rapidly into the extraction sites in 8 to 14 days, at a rate of 0.8 mm per day. Full retraction of the canines was achieved in a mean time of 10.05 (–2.01) days. The anchorage teeth were able to withstand the retraction forces with minimal anchorage loss. The mean change in canine inclination was 13.15° – 4.65°, anterior face height and mandibular plane angle increased. No clinical and radiographic evidence of complications, such as root fracture, root resorption, ankylosis, periodontal problems, and soft tissue dehiscence, was observed. Patients had minimal to moderate discomfort after the surgery. They conclude that the dentoalveolar distraction technique is an innovative method that reduces overall orthodontic treatment time by nearly 50%, with no unfavorable effects on surrounding structures.

Mezomo[42] (2011) measured the space closure during the retraction of upper permanent canines with selfligating and conventional brackets. Fifteen patients who required maxillary canine retraction into first premolar extraction sites as part of their orthodontic treatment completed this study. In a random split-mouth design, the retraction of upper canines was performed using an elastomeric chain with 150 g of force. The evaluations were performed in dental casts (T0, initial; T1, 4 weeks; T2, 8 weeks; T3, 12 weeks). The amount of movement and the rotation of the canines as well as anchorage loss of the upper first molars were evaluated. The results showed that there was no difference between self-ligating and conventional brackets regarding the distal movement of upper canines and mesial movement of first molars. Rotation of the upper canines was minimized with self-ligating brackets. He concluded that the distal movement of the upper canines and anchorage loss of the first molars were similar with both conventional and self-ligating brackets. Rotation of the upper canines during sliding mechanics was minimized with self-ligating brackets.

Seifi et al[55] (2011) determined the efficacy of low level laser therapy for clicking temporomandibular joint (TMJ) with a diode laser following orthodontic treatment. LLLT with a diode laser was used for temporomandibular clicking and postoperative findings were evaluated in a case of an orthodontic patient following the termination of treatment. Patient had a history of severe clicking before initiation of treatment protocol. Low level diode laser (wave length 808 nm, power 0.7 watt, Time 60 seconds), applied for the purpose of relieving the signs. During the process of intervention and establishing the proper dental occlusion sign of temporomandibular joint dysfunction i.e. clicking reduced significantly but remained at the lowest level from the perspective of frequency and severity index. Patient had no sign and symptom at the end of treatment. He concluded that Low level laser therapy serves as an adjuvant to orthodontic treatment while establishing the proper occlusion of stomatognathic system has pivotal role in function and stability of outcome.

Ibrahim et al[64] (2011) evaluated the effect of low level laser therapy on alveolar bone remodeling and rate of tooth movement secondary to application of orthodontic forces. 42 male Guinea pigs were used in this study. The animals were divided into two groups (each group contains 21 animals), group (1) received soft laser therapy at the treatment site and group (2) as a control group. The orthodontic device was cemented to the lower central incisors to be activated once only. Daily measurements were taken directly from the oral cavity to record the rate of tooth movement of the experimental groups. Seven animals of each group were sacrificed at 3 days, 2 weeks and one month. Radiographic assessment was carried out at these intervals using Radio-Visio- Graphy (RVG), with its personal computer (PC) based version, to monitor the changes in the bone density mesial to each lower central incisor. The lower jaws were histologically treated to obtain mesiodistal sections of the lower incisors with their supporting structures and stained by H & E. He concluded that soft laser can enhance the rate of orthodontic tooth movement due to stimulation of bone remodeling.

Long et al[37] (2012) evaluated the effectiveness of interventions on accelerating orthodontic tooth movement. They searched the databases of PubMed, Embase, Science Citation Index, CENTRAL, and SIGLE from January 1990 to August 2011 for randomized or quasirandomized controlled trials that assessed the effectiveness of interventions on accelerating orthodontic tooth movement. They concluded that among the five interventions, corticotomy is effective and safe to accelerate orthodontic tooth movement, low-level laser therapy was unable to accelerate orthodontic tooth movement, current evidence does not reveal whether electrical current and pulsed electromagnetic fields are effective in accelerating orthodontic tooth movement, and dentoalveolar or periodontal distraction is promising in accelerating orthodontic tooth movement but lacks convincing evidence.

Cepera et al[6] (2012) evaluated the effects of a low-level laser on bone regeneration in rapid maxillary expansion. From the evaluation of bone density, the results showed that the laser improved the opening of the midpalatal suture and accelerated the bone regeneration process. He concluded that the low-level laser, associated with rapid maxillary expansion, provided efficient opening of the midpalatal suture and influenced the bone regeneration process of the suture, accelerating healing.

Genc et al[20] (2012) evaluated the effects of low-level laser therapy (LLLT) on (1) the velocity of orthodontic tooth movement and (2) the nitric oxide levels in gingival crevicular fluid (GCF) during orthodontic treatment.

The sample consisted of 20 patients (14 girls, six boys) whose maxillary first premolars were extracted and canines distalized. A gallium-aluminum-arsenide (Ga-Al-As) diode laser was applied on the day 0, and the 3rd, 7th, 14th, 21st, and 28th days when the retraction of the maxillary lateral incisors was initiated. The right maxillary lateral incisors composed the study group (the laser group), whereas the left maxillary lateral incisors served as the control. The teeth in the laser group received a total of ten doses of laser application: five doses from the buccal and five doses from the palatal side (two cervical, one middle, two apical) with an output power of 20 mW and a dose of 0.71 J /cm(2). Gingival crevicular fluid samples were obtained on the above-mentioned days, and the nitric oxide levels were analyzed. He concluded that the application of low-level laser therapy accelerated orthodontic tooth movement significantly; there were no statistically significant changes in the nitric oxide levels of the gingival crevicular fluid during orthodontic treatment.

Doshi Mehta et al[15] (2012) evaluated of the efficacy of low-intensity laser therapy in reducing orthodontic treatment duration and pain. Twenty patients requiring extraction of first premolars were selected for this study. We used a randomly assigned incomplete block split-mouth design. Individual canine retraction by a nickel-titanium closed-coil spring was studied. The experimental side received infrared radiation from a semiconductor (aluminium gallium arsenide) diode laser with a wavelength of 810 nm. The laser regimen was applied on days 0, 3, 7, and 14 in the first month, and thereafter on every 15th day until complete canine retraction was achieved on the experimental side. Tooth movement was measured on progress models. Each patient's pain response was ranked according to a visual analog scale. An average increase of 30% in the rate of tooth movement was observed with the low-intensity laser therapy. Pain scores on the experimental sides were significantly lower compared with the control sides. Low-intensity laser therapy is a good option to reduce treatment duration and pain.

Yi et al[71] (2012) demonstrated that drinking coffee may accelerate orthodontic tooth movement. Drinking coffee, as a daily habit of many people, can be an effective accelerator of tooth movement with little side effect for caffeine can break the calcium balance in bone tissue and directly inhibit the development of osteoblasts, leading to temporary decreased bone mineral density and consequently inducing faster orthodontic tooth movement. He concluded that daily coffee consumption may be a promising approach to enhance orthodontic tooth movement for its reversible effect on bone mineral density and calcium balance.

Seifi et al[56] (2012) conducted a study to enhance the orthodontic tooth movement by reducing the cortical bone layer (resistant to bone re-sorption relative to spongious bone) following Erbium, Chromium doped Yttrium Scandium Gallium Garnet (Er-Cr: YSGG) laser irradiation, without reflection of surgical soft tissue flap. 8 New Zealand Male rabbits were the samples for the research. The right first premolar of each rabbit (experiment group) underwent treatment for mesial movement with 75 gram of orthodontic force by using closed Ni-Ti coil spring (Dentaurum®). Coil spring was fixed in the cervical region of first premolars by means of ligature wire and No-Mix composite (Dentaurum®) and also activated to the cervical site of incisors. The left first premolars of the subjects were considered as the control group. Laser corticotomy was performed in anesthetized rabbits. Samples were sacrificed for determination of tooth movement after initiating premolar protraction on the 21th day. The amount of orthodontic tooth movement was assessed by using a metal feeler gauge with the precision of 0.01 mm, between mesial surface of the second premolars and distal surfaces of the first premolars. The amount of orthodontic tooth movement in the experimental group (mean=1.653±0.34 mm) was significantly ($p<0.001$) greater than that of the control group (mean=0.936 ±0.28 mm). The innovated laser assisted corticotomies enhanced the rate of orthodontic tooth movement on the intervention side, significantly ($p<0.001$). He concluded that the innovated method of laser assisted flapless corticotomy is a useful procedure for reducing treatment time and damage to periodontium. It also eliminates the necessity of more invasive intervention of flap surgery.

Fernando et al[18] (2012) aimed to assess histologic changes after the use of laser phototherapy (LPT) during induced tooth movement with 40 g/F on young adult male rats. Thirty animals were divided into two groups (n=15), named according to the time of animal death (7, 13, and 19 days). Half of the animals in each group were subjected to irradiation with infrared (IR) laser , the other half were used as nonirradiated controls. After animal death, specimens were sectioned, processed, and stained with hematoxylin and eosin (HE) and Sirius Red, and were used for semi-quantitative histologic analysis by light microscopy. He found that LPT positively affected an important aspect of dental movement; the hyalinization. He also found a significant reduced expression of hyalinization after 19 days. On irradiated subjects, hyalinization was increased at day 7 with significant reduction at day 13. He concluded that it is possible to conclude that the use of laser light caused histologic alterations during the orthodontic movement characterized by increased formation of areas of hyalinization at early stages, and late reduction when compared to nonirradiated animals.

Duan et al[16] (2012) compared the speed of the orthodontic tooth movement of rat molars under continuous wave (CW) and pulsed wave (PW) low-level laser therapy (LLLT). Orthodontic movement was induced in 40 rats with 10g coil springs. Rats were randomly assigned to five groups. In Group I, the maxillary left first molars were irradiated with CW by a gallium aluminum arsenide (GaAlAs) diode laser source (830nm, 180mW, 3.6J/cm(2), and 0.9W/cm(2) for 4sec at three locations for 3 consecutive days). In Groups II, III, and IV, animals were irradiated with PW at 2, 4, and 8Hz, respectively (50% duty cycle, average power of 90mW, 3.6J/cm(2), and 0.45W/cm(2) for

8sec at three locations for 3 consecutive days). Group V served as the control (no irradiation). The movement distance was measured on days 3, 7, and 14. He concluded that the CW and PW treatments both led to faster orthodontic tooth movement compared with the control group.

Altan et al[3] (2012) evaluated the effects of 820-nm diode laser on osteoclastic and osteoblastic cell proliferation-activity and RANKL/OPG release during orthodontic tooth movement. Thirty-eight albino Wistar rats were used for this experiment. Maxillary incisors of the subjects were moved orthodontically by a helical spring with force of 20 g. An 820-nm Ga-Al-As diode laser with an output power of 100 mW and a fiber probe with spot size of 2 mm in diameter were used for laser treatment and irradiations were performed on 5 points at the distal side of the tooth root on the first, second, and 3rd days of the experiment. Total laser energy of 54 J (100 mW, 3.18 W/cm(2), 1717.2 J/cm(2)) was applied to group II and a total of 15 J (100 mW, 3.18 W/cm(2), 477 J/cm(2)) to group III. The experiment lasted for 8 days. The number of osteoclasts, osteoblasts, inflammatory cells and capillaries, and new bone formation were evaluated histologically. Immunohistochemical parameters were higher in group III than in group I, while both were lower than group II. On the basis of these findings, he concluded that low-level laser irradiation accelerates the bone remodeling process by stimulating osteoblastic and osteoclastic cell proliferation and function during orthodontic tooth movement.

MATERIALS AND METHODS

A group of 13 patients, in which 7 males and 6 females were selected undergoing orthodontic treatment at Ragas Dental College and Hospital. The mean age of the patients was 21 ± 4 years. The upper and lower first bicuspids were extracted in these patients as a part of orthodontic treatment. For each patient, the diagnosis and treatment plan was formulated based on a standard orthodontic documentation with photographs, model casts, cephalometric, and panoramic radiographs. Prior to the start of study, the procedure was explained in detail and the possible side effects mentioned. A written consent was obtained from these patients (Fig 1). The study protocol was approved by the institutional research ethics committee.

The patients selected fulfilled the following criteria:

- All permanent teeth erupted excluding the third molars in the maxillary arch.
- Root formation completed till the second molars.

The exclusion criteria included

- Patients with previous orthodontic history
- Presence of periodontal pathology and those having dilacerated tooth.
- Those undergoing medical treatment and are on medication with drugs like non-steroidal anti-inflammatory drugs (NSAID'S) and steroid therapy were ruled out as it interferes with bone metabolism and could hinder the results.

MATERIALS

- 20 gauge stainless steel wire. (Fig. 2)
- Ligature wire of 0.009 inch thickness (Rocky Mountain Orthodontics, USA) (Fig. 3)
- NiTi coil springs(Rocky Mountain Orthodontics, USA) (Fig.4)
- Dontrix Gauge (Ormco, USA) (Fig. 5)
- Upper 0.18 stainless steel arch wire.(Rocky Mountain Orthodontics, USA) (Fig.6)
- Diode laser (Ezlase 940, BIOLASE, USA) (Fig. 7)
- White Light Scanner (3D Scan solutions, India)(Fig. 8)
- 3D images of scanned models (Fig. 9)

STUDY DESIGN

All patients were treated with a standard 0.022-inch slot pre - adjusted edgewise brackets. After leveling and aligning was complete, the anterior four teeth were consolidated using a 0.009 inch ligature wire (Fig 3). The second premolar and the first molar was also made into a single unit. A transpalatal arch made of 20 gauge stainless steel wire was inserted extending between 1st molars to reinforce anchorage (Fig 2). Retraction was performed on 0.18 inch stainless steel arch wire. The canines were individually ligated using the same ligature wire. NiTi coil springs (Fig 4) were used for individual retraction of the canines.

Laser irradiation

A diode laser (Ezlase 940, BIOLASE, USA) was used in this study (Fig 7). The major component of this system consists of the laser device itself, a delivery system, and a controller. The output of this laser is controlled electronically, where microprocessor controllers are used. This allows the specialist to alter most aspects of the laser output. The 940 nm wavelength exclusively for dentistry by Biolase is better absorbed by hemoglobin and oxyhemoglobin than other wavelengths so that the ezlase works efficiently at low power and with less heat. In addition to this it has an exclusive beam – dispersing hand piece which makes it a state - of - the - art - equipment.

Before start of laser irradiation, protective goggles were worn, both by the operator and the patient to eliminate the potential hazards of laser (Fig 7). These glasses were provided by the manufacturer and had an optical density (OD) of 4+. This OD was in accordance with the 940 nm wavelength used. It allows penetration of the laser only 0.0001 mm which meant that the depth of exposure is minimal. To prevent intraoperator variations, all irradiations were done by the same operator.

The study was a split mouth design, with one quadrant of the maxillary arch irradiated with the laser, whereas the other side taken as a control. The diode laser was operated at 100 mW output with the energy set at 80 Joules (Fig 7).

The patients were irradiated every 10 days for a period of two months. A total of 5 areas were irradiated both on the labial and palatal PDL of the canines on the root each for a period of 15 seconds (Fig 10).

These areas were:

1. Mesio–Cervical
2. Disto–Cervical
3. Middle
4. Mesio-Apical
5. Disto-Apical

The canine retraction was performed using NiTi coil springs [Rocky Mountain Orthodontics (RMO)] (Fig. 11). The spring was activated to deliver 150 gms of force, which was measured using a Dontrix gauge (Ormco, Italy). This force level was maintained throughout the entire study. (Fig. 12)

Analysis of the rate of orthodontic tooth movement

White light scanning

White light scanning is a 3d-scanning process using non-contact optical scanning device which uses white light source to project fringes on the part being scanned. The sensor of the scanner which is equipped with two cameras take several images of the part during the measurement and sends the images to a high end PC where advanced image software calculates point co-ordinates throughout the visible area of the part under the scan. The data is of high accuracy and the repeatability of the white light scanners is between 1-5 microns.

Using this scanner the casts obtained before (T_1) and after 2 months of retraction (T_2) (Fig 13) were scanned and the resultant 3 dimensional data were fed into the Geomagic Studio software.(Fig. 14)

Determining the amount of tooth movement

The Geomagic studio software was used in this study. This software was used for making measurements which was done by a well trained specialist in the field of reverse engineering. It is one of the most powerful, precise and a user friendly reverse engineering and point cloud software. This software was used to interpret the total tooth movement following two months of study.

The amount of tooth movement in millimeters was analyzed by measuring the distance between the following reference points on dental models:

1. The tip of the mesial cusp of the first molar
2. The tip of the canine

The measurement recorder was blinded about the control and experimental sides.

Analysis of Individual canine movement

The casts obtained before retraction (T_1) and after 2 months of retraction (T_2) were scanned and the resultant data were fed into the Geomagic studio software. Both the scanned imaged were then superimposed in the software using the following reference points: (Fig. 15)

1. Anteriorly the central and lateral incisors.
2. Posteriorly the 2nd molars on both the quadrants.

Using these results the individual movement of canine was recorded.

Determination of the amount of anchorage loss

The same procedure followed for assessing the individual canine movement was advocated to determine the mesial movement of 1^{st} molars.

STATISTICAL ANALYSIS

The data obtained by making these measurements were statistically analyzed using the SPSS v.17 (SPSS Inc., Chicago, Illinois, USA). The descriptive statistics for the mean difference and standard deviations were calculated for all variables.

Unpaired‘t’ test was used to compare the variables between the groups. After the analysis, the data were sorted into various tables based on the objectives of the study.

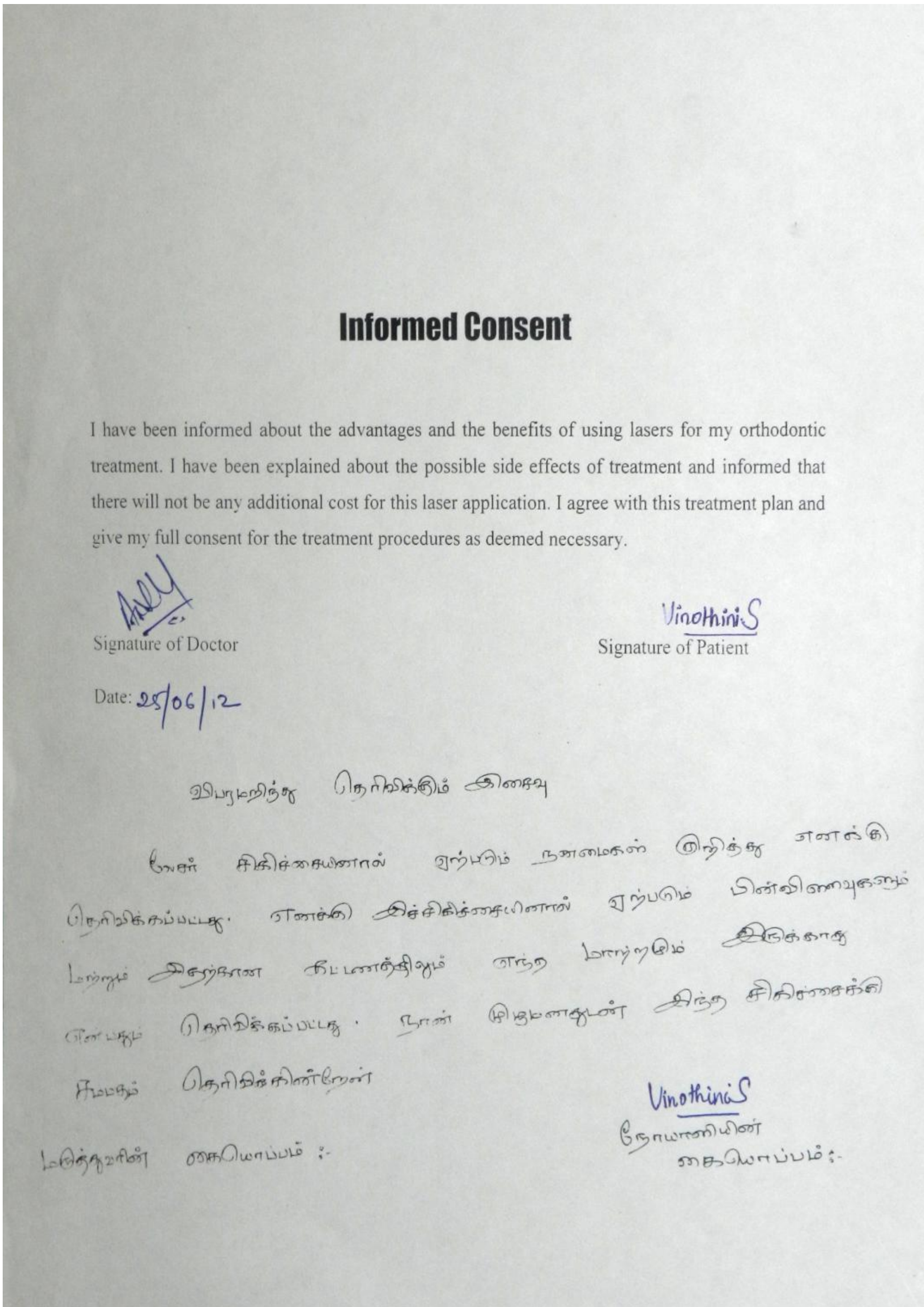
RESULTS

To study the differences in tooth movement between the lased and non-lased side an unpaired ‘t’ test was done. **Table 1** shows the comparison of tooth movement between the lased and non-lased side following 2 months of study. The mean tooth movement for the 13 patients are shown in **Table 2**

The mean tooth movement measured from the canine cusp tip to mesio-buccal cusp of 1^{st} molar in the control group is 1.9145 ± 0.95043 with a significant P value of 0.001. The mean tooth movement on the lased side was 3.4985 ± 1.09410 mm.

Table 3 shows the individual movement of the canine in a period of 2 months. When an unpaired ‘t’test was carried out in the 13 patients the control group showed a mean canine tooth movement of 1.5302 ± 0.57490 and lased group showed a mean canine tooth movement of 2.7673 ± 0.99867 with a significant P value of 0.001. (**Table 4**)

The amount of anchorage loss during the 2 month study is given in **Table 5**. An unpaired ‘t’test was used to determine the mean molar movement. (**Table 6**) The control side showed a mean molar movement of 0.6440 ± 0.33056. The lased side had a mean value of 0.4610 ± 0.23679.



Informed Consent

I have been informed about the advantages and the benefits of using lasers for my orthodontic treatment. I have been explained about the possible side effects of treatment and informed that there will not be any additional cost for this laser application. I agree with this treatment plan and give my full consent for the treatment procedures as deemed necessary.

Signature of Doctor

Vinothini S
Signature of Patient

Date: 25/06/12

விபரமறிந்து தெரிவிக்கும் இசைவு

லேசர் சிகிச்சையினால் ஏற்படும் நன்மைகள் குறித்து எனக்கு தெரிவிக்கப்பட்டது. எனக்கு இச்சிகிச்சையினால் ஏற்படும் பின்விளைவுகளும் மற்றும் கூடுதலான கட்டணத்திலும் எந்த மாற்றமும் இருக்காது என்பதும் தெரிவிக்கப்பட்டது. நான் முழுமனதுடன் இந்த சிகிச்சைக்கு சம்மதம் தெரிவிக்கின்றேன்

Vinothini S

மருத்துவரின் கையொப்பம் :-

நோயாளியின் கையொப்பம் :-

Fig.1 – CONSENT FORM

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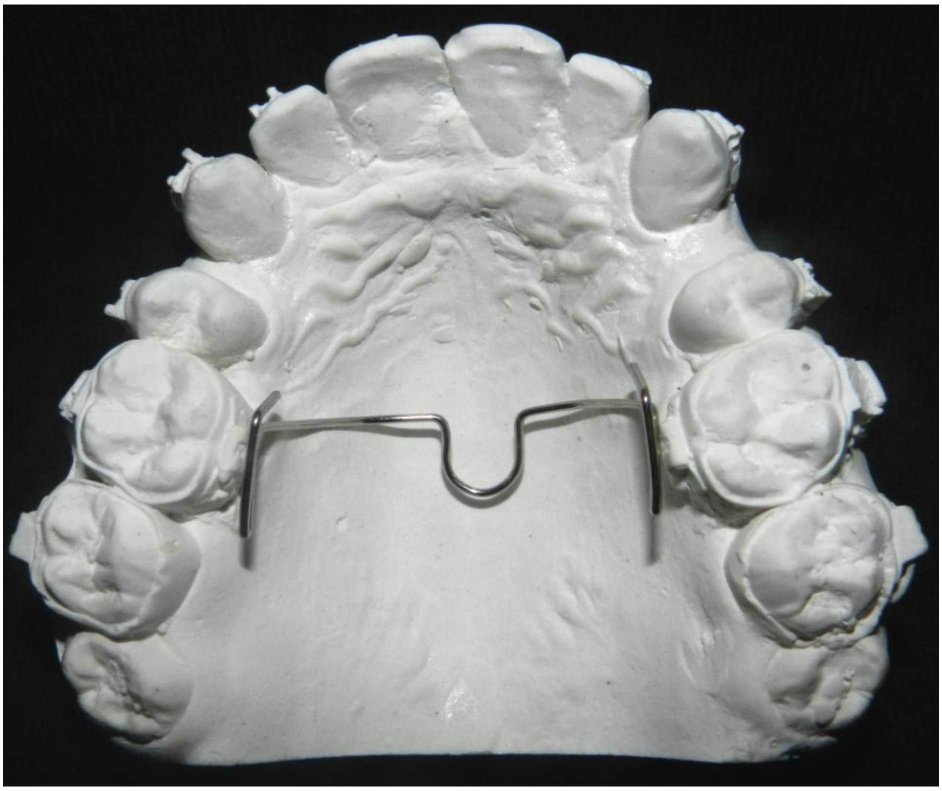
Fig 2 : 20 GUAGE STAINLESS STEEL WIRE FOR MAKING TRANSPALATAL ARCH



TRANSPALATAL ARCH MADE FROM 20 GAUGE STAINLESS STEEL WIRE

Fig 3 : 0.009 INCH STAINLESS STEEL LIGATURE WIRE (RMO, USA)

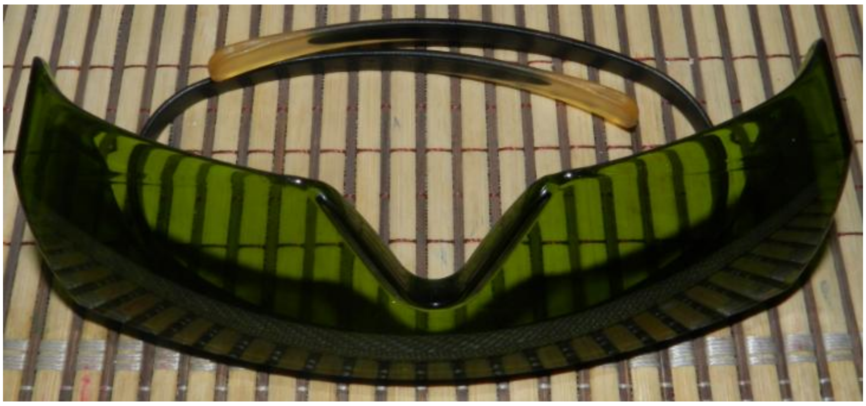
Fig 4 : NiTi COIL SPRINGS (RMO, USA)

Fig 5 : DONTRIX GAUGE, (ORMCO, USA)

Fig 6: 0.18 INCH STAINLESS STEEL ARCH WIRE (RMO, USA)

Laser unit displaying the power and energy

Handpiece



Saftey goggles provided by the manufacturer

Fig 7: Ezlase 940, DIODE LASER

Fig 8 : WHITE LIGHT SCANNER

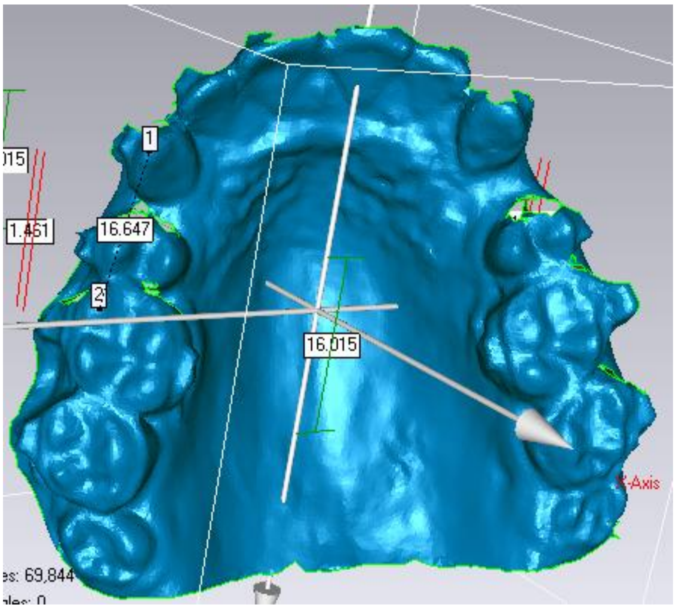
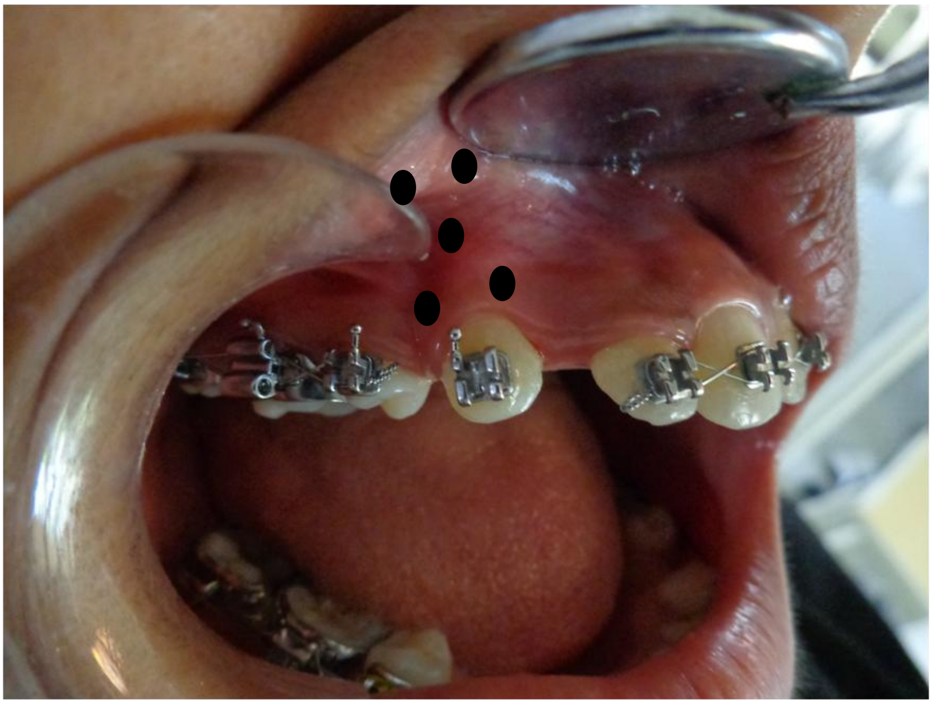
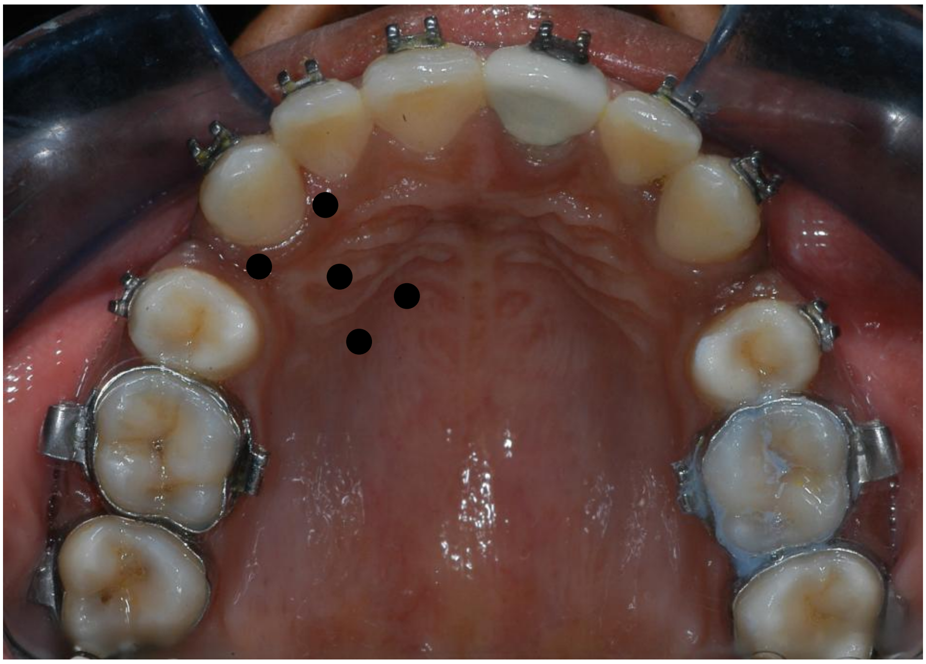


Fig 9 : 3D image of scanned model



LABIAL SIDE



PALATAL SIDE

Fig 10: LASER IRRADIATION POINTS

Fig 11: Niti coil spring loaded with a force of 150gms

Fig 12 : Force of 150 gms measured using dontrix gauge

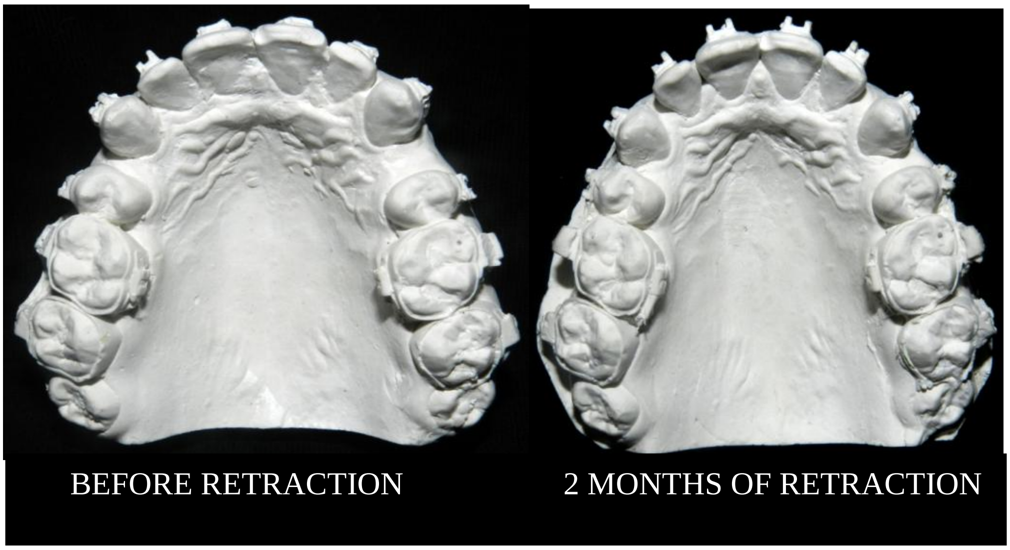
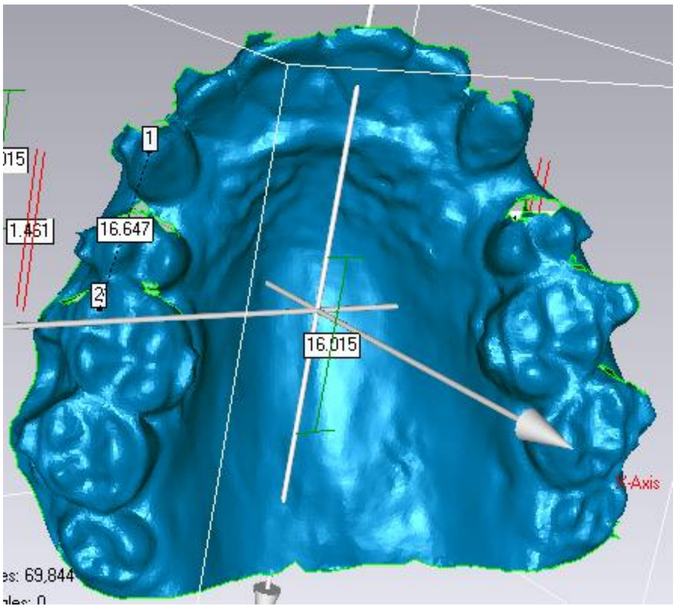
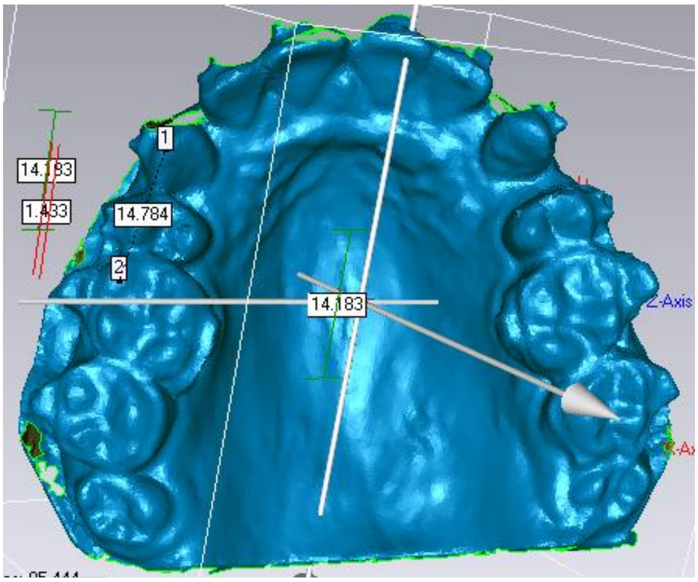


Fig. 13: DENTAL CAST OBTAINED PRIOR TO START OF RETRACTION AND AT 2 MONTHS OF RETRACTION



BEFORE RETRACTION



AFTER 2 MONTHS OF RETRACTION

Fig 14 : 3D image of scanned model

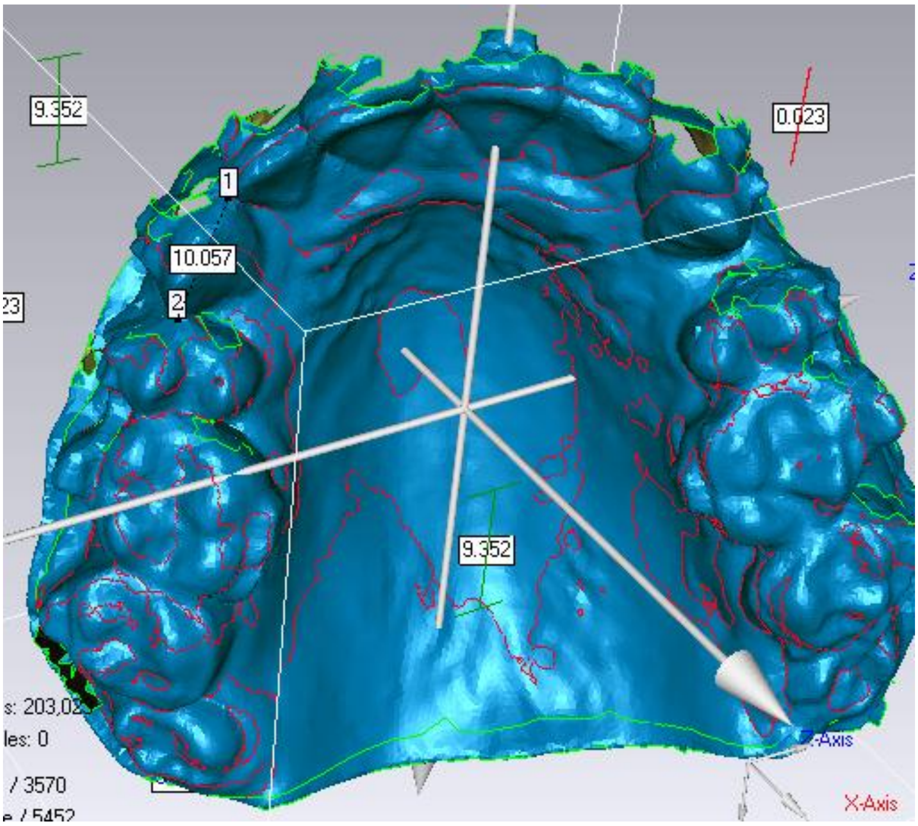


Fig 15: SUPERIMPOSED IMAGE

TOOTH MOVEMENT IN 2 MONTHS

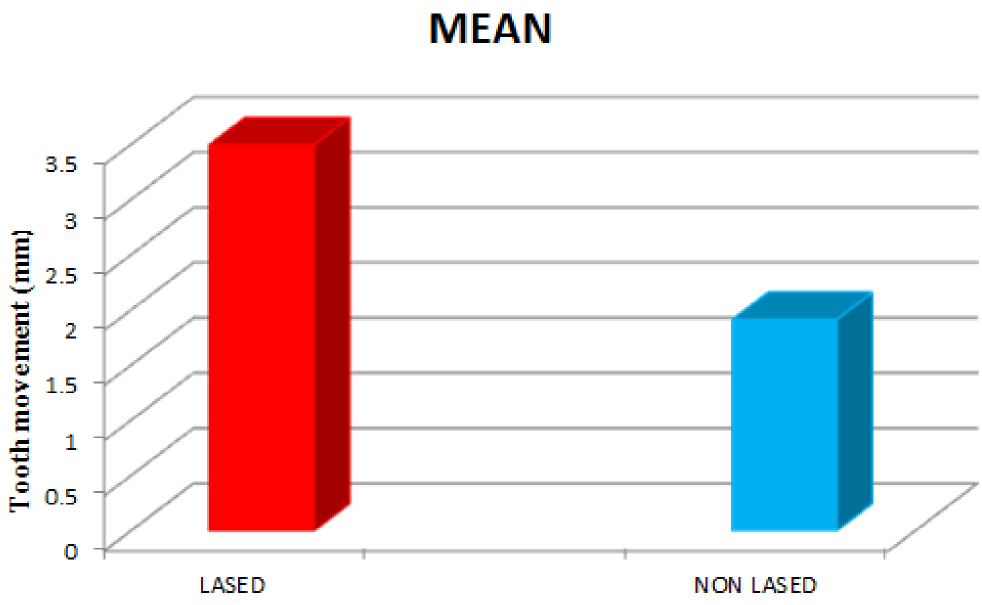


Fig. 16 - The effect of low level lasers on the amount of tooth movement is plotted by median of lased and non lased groups

INDIVIDUAL CANINE MOVEMENT

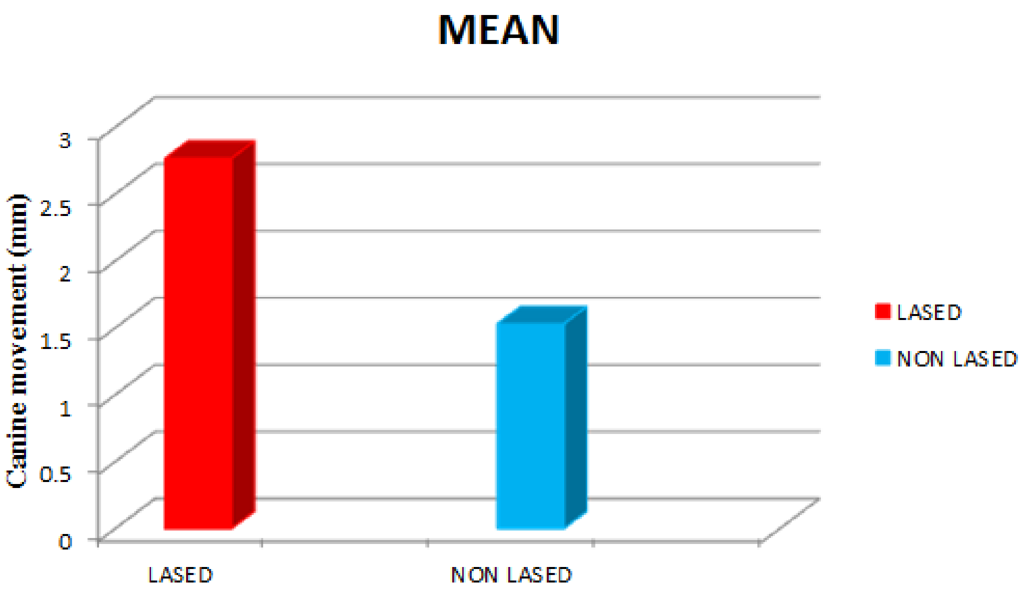


Fig.17: The effect of low level lasers on the movement of canines plotted by median of lased and non lased groups

TOOTH MOVEMENT AFTER TWO MONTHS OF RETRACTION (Table 1)

	LASED SIDE			NON - LASED SIDE		
PATIENTS	***Before start of retraction (T_1)***	***2 months after retraction (T_2)***	***Tooth movement (mm)***	***Before start of retraction (T_1)***	***2 months after retraction (T_2)***	***Tooth movement (mm)***
PATIENT 1	**19.363**	**14.720**	**4.643**	**19.436**	**15.249**	**4.187**
PATIENT 2	**20.716**	**15.016**	**3.852**	**21.337**	**18.589**	**2.621**
PATIENT 3	**17.451**	**15.467**	**1.984**	**18.140**	**16.835**	**1.305**
PATIENT 4	**19.160**	**16.673**	**2.487**	**18.720**	**17.037**	**1.683**
PATIENT 5	**19.538**	**16.513**	**3.025**	**16.547**	**15.922**	**0.625**
PATIENT 6	**21.653**	**18.797**	**2.856**	**22.829**	**20.585**	**2.244**
PATIENT 7	**20.610**	**16. 372**	**2.882**	**16.435**	**15.202**	**1.233**
PATIENT 8	**22.084**	**20.063**	**2.021**	**24.782**	**23.148**	**1.634**
PATIENT 9	**16.537**	**13.027**	**3.51**	**17.247**	**14.912**	**2.335**
PATIENT 10	**21.611**	**17.310**	**2.503**	**16.647**	**14.784**	**1.863**
PATIENT 11	**19.284**	**15.895**	**3.389**	**18.105**	**15.561**	**2.544**
PATIENT 12	**19.538**	**16.513**	**3.025**	**16.547**	**15.922**	**0.625**
PATIENT 3	**21.611**	**17.310**	**2.503**	**16.647**	**14.784**	**1.863**

Total tooth movement both on the laser applied and non – lased side measured from the canine cusp tip to mesio-buccal cusp of maxillary first molar. T_1 = Pre retraction measurements, T_2 = Post retraction measurements

Table 2

	Side	N	Mean	Std. Deviation
Tooth Movement Measurement (Measured from the canine cusp tip to mesio-buccal cusp tip of Ist molar)	Lased	13	2.975	0.742
	Non_Lased	13	1.9145	.95043

Level of significance P value = 0.001

CANINE MOVEMENT (Table 3)

	LASED SIDE	NON - LASED SIDE
PATIENTS	***Difference between T_1 and T_2***	***Difference between T_1 and T_2***
PATIENT 1	**3.96**	**3.048**
PATIENT 2	**2.849**	**2.248**
PATIENT 3	**1.283**	**1.07**
PATIENT 4	**1.98**	**1.244**
PATIENT 5	**1.979**	**1.304**
PATIENT 6	**2.231**	**1.489**
PATIENT 7	**1.715**	**1.031**
PATIENT 8	**1.883**	**1.012**
PATIENT 9	**2.486**	**1.67**
PATIENT 10	**2.353**	**1.305**
PATIENT 11	**2.924**	**1.863**
PATIENT 12	**1.979**	**1.304**
PATIENT 13	**2.353**	**1.305**

Individual movement of canine both on the lased and non – lased side.

Table 4

	Side	N	Mean	Std. Deviation
Individual Tooth Movement (Canine Tooth)	Lased	13	2.436	.66367
	Non_Lased	13	1.5302	.57490

Level of significance P value = 0.001

DISCUSSION

The term "**accelerated orthodontic treatment**" is a contentious subject. The average time required to complete an orthodontic treatment is 2- to 3-years which is arduous for patient. Hence it is obligatory to accelerate alveolar bone remodeling during treatment to abbreviate the time required[36]. The treatment time depends on distances the teeth need to be moved, treatment goals, type of techniques employed and the cooperation of the patient. During the past two decades many different approaches to fasten tooth movement have been employed. Some attempts have been more creative than others. It started in 1970's with the evolution of powered brackets each having a tiny working motor[39]. Over the years low voltage currents[13], magnets[11], injection of chemical agents[70] and certain invasive procedures like corticotomy[56] and distraction osteogenesis[2] have been employed to enhance tooth movement. Owing to the demerits of the above procedures, other effective methods have been searched for.

Davidovitch in 1980 examined the effects of electric currents on orthodontic tooth movement. He concluded that electric currents, when applied non - invasively to gingival tissues, are capable of activating many PDL cells and neighbouring osteoblasts. This effect is localized to well-defined zones near the electrodes and, therefore, may be used in areas where bone remodelling is desired, such as in the case of orthodontic treatment.[12]

Accelerated Osteogenic Orthodontics or Wilckodontics is a surgical intervention limited to the cortical portion of the alveolar bone. The biological stimulus generated by corticotomies is reflected in the structure of trabecular bone, which provides an opportunity to enhance certain orthodontic movements[56].

Distraction osteogenesis was used as early as 1905 by Codivilla and was later popularized by the clinical and research studies of Ilizarov. Distraction osteogenesis was performed in the human mandible by Guerrero in 1990 and by McCarthy et al in 1992. Cortical holes are made in the alveolar bone with a small, round, carbide bur. A thin, tapered, fissure bur was used to connect the holes around the root. Akhare et al reviewed the effects of distraction osteogenesis assisted canine retraction. He concluded that dentoalveolar distraction technique is an innovative method that reduces overall orthodontic treatment time by nearly 50%[2].

Recently the OrthoAccel®'s (OA) Technology is predicated on the application of pulsating, low magnitude forces (cyclic forces) to the teeth and surrounding bone as a means of accelerating orthodontic tooth movement. The OA appliance is a removable device similar to a retainer with a small motor, into which the patient bites. Rather than using only constant pressure, the device applies very light vibrations to the dentition. The patient places and activates the device daily for twenty minutes of gentle pulsing. This technology has revealed to accelerate tooth movement.

In 1967, few years after the first working laser was invented, Endre Mester in Hungary tested carcinogenic potential in mice. He shaved the dorsal hair, divided them into two groups and gave a laser treatment with a low powered ruby laser (694-nm) to one group. The irradiated group expressed no carcinogenicity and instead to his surprise found that the hair on the treated group grew back more quickly than the untreated group. This was the first demonstration of "laser biostimulation". One important point that has been demonstrated by multiple studies in cell culture, animal models and in clinical studies is the concept of a biphasic dose response when the outcome is compared with the total delivered light energy density[41].

The technology of Low Level Laser Therapy (LLLT) has proved to be a boon in the field of orthodontics. The past decade has seen a veritable explosion of research into the clinical applications of LLLT in orthodontics. Majority of the applications of low level laser therapy (LLLT) in dentistry are directed toward soft tissues and in recent years there has been increasing interest in orthodontic applications of LLLT.

The documented literatures available on examining the effects of LLLT on orthodontic tooth movement are scant. LLLT has shown to be an effective tool in causing a biomodulatory effects on bone regeneration which means that it may also have a considerable effect in accelerating orthodontic tooth movement[47].

Saito and Shimizu found that low intensity laser therapy can accelerate bone regeneration in the midpalatal suture during rapid palatal expansion and stimulate the synthesis of collagen, which is major matrix protein in bone[52]. In the following years, Kawasaki and Shimizu performed another experiment on rats to find the effect of LLLT on orthodontic tooth movement. From his study he inferred that orthodontically induced tooth movement associated with LLLT produced an increase in the vascularization and this factor could accelerate pulp tissue repair. He also showed that low level laser therapy had a net effect of 30% increase in tooth movement[29]. However its effect on tooth movement in humans still remains uncertain.

Hence our study aimed at finding out the effects of Low Level Laser Therapy on the rate of orthodontic tooth movement. We used a sample size of 13 patients in our study who had their upper and lower first bicuspids were extracted for orthodontic treatment. We chose patients who had all permanent teeth erupted with root formation completed excluding the third molars in the maxillary arch. Patients with previous orthodontic history, with the presence of periodontal pathology and those undergoing medical treatment and are on medication with drugs like non-steroidal anti-inflammatory drugs (NSAID'S) and steroid therapy were ruled out.

Stainless steel wire (Rocky Mountain Orthodontics, USA) of 0.18 inch diameter was placed in the arch on which retraction was initiated. It is known Tooth movement can be influenced by the type of material and diameter of orthodontic archwire especially during sliding mechanics. It is known that stiffer wires can better resist the tendency of teeth tilting during sliding. Moreover, friction increases as bracket slots are filled. For these reasons, a round, 0.018-inch SS arch wire (RMO) was selected[42]. The canine bracket was secured tightly with stainless steel ligatures as elastomeric modules tend to lose its elasticity and cause rotation during retraction.

The Ezlase 940 (Biolase) diode laser was used to irradiate the canines prior to retraction According to the International Electrotecnical Commission (IEC) 60825 – 1 standard this laser was classified as class 4 lasers. It had a standardized wavelength of 940 nm, with an output power of 100 mW, and an exposure time of 15 seconds per spot (mesio-cervical, disto-cervical, middle, mesio-apical, disto-apical areas of the canine root). The 940 nm wavelength works efficiently at low power. The low power was well absorbed by hemoglobin and oxyhemoglobin. Hence only less amount of heat was produced.

The wavelength at which the laser emits determines the effective depth of penetration, within the tissue. The ability of a low level laser to penetrate a given material depends on several factors. The most significant of these is the absorption coefficient of the material through which the laser light travels[70]. Matter preferentially absorbs light at varying wavelengths. Laser photons that travel through a given material with a high absorption coefficient for its specific wavelength will lose energy through absorption more readily than a material with a lower coefficient for that material. Because these photons are readily absorbed, this light travels much shorter distances than those light wavelengths that are not absorbed. The absorption of photons from a laser's initial ray effectually degrades the power of light with distance travelled. In most circumstances only a fraction of the photons from the initial beam may reach these depths[63].

The laser irradiation was done once in 10 days for a period of 2 months. Impressions were made prior to irradiation (T_1) and after two months of retraction (T_2). We chose to irradiate on 5 areas both on the lingual and buccal periodontal ligament of canines for a period of 15 seconds per spot[10]. These areas were selected according to the work of Cruz et al. The reasons for choosing these areas were in order to cover the periodontal fibres and alveolar process around the canine tooth.

Before the start of laser irradiation, protective goggles were worn both by the operator and the patient to avoid any optical hazards. These glasses were provided by the manufacturer and had an optical density (OD) of 4+. This OD was in accordance with the 940 nm wavelength used. It allows penetration of the laser only 0.0001 mm which meant that the intensity of exposure is extremely negligible.

Nickel titanium coil springs (Rocky Mountain Orthodontics, USA) were used for retraction of the canines on both lased and non-lased sides. These springs provide a force level that could be maintained for a longer period of time[5]. Barlow et al in 2008 evaluated the factors influencing the efficacy of sliding mechanics to close an extraction space. He concluded that nickel-titanium coil springs produce a more consistent force when compared with elastomeric chains as a method of force delivery to close extraction space along a continuous arch wire[4].

The force selected for retraction of canines was 150 gms which was measured using a Dontrix gauge (Ormco, Italy). Quinn and Yoshikawa estimated that a force between 100 and 200 gms would be ideal for canine retraction[49]. Retain et al stated that the initial force application should be light, because this produces biologic effects. These lighter forces will produce less extensive hyalinized tissue that can be readily replaced by cellular elements. He stated that an appropriate force of 150 to 200gms for maxillary canines should be used for translatory movement[27].

Models obtained before irradiation (T_1) and after 2 months of canine retraction (T_2) were scanned using a white light scanner. White light scanning is a 3d-scanning process using non-contact optical scanning device which uses white light source to project fringes on the part being scanned. The sensor of the scanner which is equipped with two cameras take several images of the part during the measurement and the scanned images were imported o a high end PC where advanced image software calculates point co-ordinates throughout the visible area of the part under the scan.

Khaled et al in 2008 developed a new method for three dimensional imaging of the dental cast and evaluated it's accuracy in analyzing the different tooth movements. Each subject was clinically examined, and an orthodontic diagnostic study cast was recorded. A 3D computer program was specially designed for more accurate evaluation of the dental effects induced by the three types of maxillary expanders, for the rotation and extrusion. He concluded that the reliability of generating 3D dental images using dental casts for 3D tooth movement analysis has a great research potential in orthodontics because of its ability to yield accurate and reproducible data[30].

From the scanned data obtained by white light scanning, the amount of tooth movement was analysed. This was accomplished by using the Geomagic studio software. Using this software it was also possible to measure the individual movement of the canine and the anchorage loss (mesial movement of molars) which was done by superimposing both of the models obtained before irradiation (T_1) and after 2 months of canine retraction (T_2). Geomagic scanning and design software solutions are used to capture and model 3D content from physical objects, organically sculpt complex shapes, and prepare products for manufacturing. In addition, it produces powerful 3D metrology and inspection software that verifies dimensional quality by comparing as-built products to master designs. The key features of this software are:

- Produces the most accurate scan and probe data for creating high quality 3 dimensional (3D), supporting all standard measurement systems.

- Integrates accurate 3 dimensional (3D) data directly into parametric CAD systems for immediate use in design.

It processes the scan and probe data by collecting point data from all major 3D scanners, digitizers and probes. Moreover it also optimizes scan data i.e. any overlap of irrelevant data can be removed easily. In addition to this it automatically or manually registers and merges multiple scan data sets.

Many theories have been postulated about the mechanism of action for low level lasers. In literature, the most common discussed theories are:

- **Bioluminescence theory** - DNA replication emits light at 630 nm. Since this is very close to the wavelength of the He Ne-laser light, it is postulated that laser may accelerate DNA replication via photonic stimulation. Laser irradiation at this frequency is said to be non mutagenic since it is not in the range to alter the genetic program by affecting chromosomal ultra structure. The latter is more likely to occur at ultra-violet light irradiation at 300 to 400 nm[59].
- **Cellular oscillation theory –** The laser beam carries electromagnetic oscillations of definite frequency. When it reaches the tissues the electromagnetic oscillations gradually “swing and excite” single cells.

This is thought to eventually intensify the biochemical processes that ultimately regulate the performance of various vital organs[59].

- **Biological field theory –** connections between tissues and organs in the intact organism are not limited to humeral effects and nervous control mechanisms alone. Rather there exists unique around every cell, tissue and organ and higher structural levels exerting a normalizing influence on lower levels. The resonance effect of the low power laser is thought to restore the normal energetic status of the organism, that is, restore its normal physiological state[59].

All three theories share the basic premise that laser causes activation in the cell, which in turn leads to an intensification of the biochemical processes. It is within this context that the Arndt-Schutz law becomes important with respect to low power laser application. This biological law states that "weak stimuli excite physiological activity, moderately strong ones favor it, strong ones retard it and very strong ones arrest it." [59]

In addition to the above theories, most recognized theory to explain the effects of low level lasers is the **PHOTOCHEMICAL THEORY**.[59] According to this theory; the light is absorbed by certain molecules, followed by a cascade of biologic events. The common photoreceptors are the endogenous porphyrins and cytochrome c-oxidase, leading to increased ATP production. The principle of using LLLT is to supply direct biostimulative light energy to the body cells. Cellular photoreceptors can absorb low level laser light and pass it on to mitochondria which promptly produces the cells fuel, ATP[59].

In general Low Level Laser Therapy (LLLT) works on the principle of inducing a biological response through energy transfer, in that the photonic energy delivered into the tissue by the laser modulates the biological processes within that tissue, and those within the biological system of which that tissue is a part[43].

Our study evaluated the differences in tooth movement between the lased and non lased sides. The lased side showed a mean tooth movement of 2.975 ± 0.742mm. On the non lased side the total movement was recorded to be 1.91 ± 0.95 mm (Fig. 16). To ensure precise measurements of canine retraction and anchorage loss, individual movement of both the canines and molars were recorded using a white light scanner. The canine moved at a mean distance of 2.436 ± 0.663 mm on lased side and 1.53 ± 0.57 mm (Fig. 17) on control side. The anchorage loss during retraction was about 0.64 ± 0.33 mm on lased side and 0.46 ± 0.23mm on non – lased side. Overall there was a significant increase in the rate of tooth movement on the irradiated side. The lased side showed about 35.66% increase in the rate of tooth movement. The canine moved 32.72% more on the lased side. This increase was in accordance with the work of Cruz et al who reported about 30%[10], Youssef et al who showed a 20-40% increase[73] and Doshi Mehta et al who showed 56 % increase[15] in the tooth movement on the lased side following low level laser therapy.

It was Cruz et al in 2004, who conducted the first human study on the effect of low-intensity laser therapy on orthodontic tooth movement. They showed that the irradiated canines were retracted at a rate 34% greater than the control canines over 60 days. He concluded that LLLT significantly accelerates orthodontic movement in humans with a healthy response from periodontal tissues. Therefore it can be considered in order to shorten the treatment duration[10].

The reason for the difference in tooth movement on the lased and non lased side may be due to the fact that low level laser irradiation promotes proliferation and differentiation of human osteoblasts[61]. Its effects were studied by Stein et al in 2005 who investigated the effect of low-level laser irradiation on proliferation and differentiation of a human osteoblast cell line. They used cultured osteoblast cells which was irradiated using He-Ne laser having a wavelength of 632 nm with a power output of 10 mW. They noticed a significant 31–58% increase in cell survival (MTT assay) and higher cell count in the once-irradiated as compared to non- irradiated cells. Differentiation and maturation of the cells was followed by osteogenic markers: alkaline phosphatase (ALP), osteopontin (OP), and bone sialoprotein (BSP). A two-fold enhancement of ALP activity and expression of OP and BSP was much higher in the irradiated cells as compared to non-irradiated osteoblasts. They concluded that LLLT given for a short duration can significantly promote proliferation and differentiation of human osteoblasts in vitro as compared to non - irradiated cells. He also assumed that osteoblasts that proliferate and differentiate at a higher rate at the site of injury may increase the rate of calcium accumulation and promote bone repair. Thus, the results of the present study may suggest the ability of LLLT to enhance bone repair also in humans[61].

It is important to consider the following points when learning about the mechanisms of low level laser therapy. The coherence of the electromagnetic energy plays a crucial role in the efficacy of the treatment[63]. This degree of coherence is related to the spectral narrowness of the light source. Furthermore, the coherent character of the laser light is not lost after penetrating the tissue but is split into small coherent and polarized islands called speckles. The speckle pattern is maintained through the irradiated volume of tissue. Due to intensity differences within the speckle field, temperature and electric field gradients occur. Such gradients create a force on the cells and organelles. This explains how low level lasers have a stimulative effect on the irradiated tissue[63].

On the contrary, our results were in contradiction to the work done by Limpanichkul[36] and colleagues who conducted their clinical study on human subjects. Their results showed no difference between the experimental low-intensity laser therapy subjects and the controls in a split-mouth study with human subjects over 4 months. LLLT at the parameter settings in the study had no effect on rate of tooth movement at any time periods. He claimed that the energy density of 25 J per square centimeter was probably too low to express either stimulatory effect or inhibitory effect on the rate of orthodontic tooth movement. This may be the reason for the negative result obtained in the study.

To ensure precise measurements of the canine retraction and anchorage loss, individual movement of both the canines and molars were also recorded using a white light scanner. White light scanning provides accurate linear measurements as the reproducibility of the white light scanners is between 1-5 microns.

Despite the fact that the positive results of this study was found to be statistically significant, it lacked evidence regarding the efficiency of LLLT in reducing the treatment time all together. Therefore future studies with larger clinical trials in various malocclusions over a longer period of time are warranted.

SUMMARY AND CONCLUSION

The effect of low level laser therapy (LLLT) on the rate of orthodontic tooth movement was evaluated. 13 patients who required retraction of maxillary canines as part of orthodontic treatment were selected for this study. One side of the quadrant was lased with a diode laser while the other side taken as control. NiTi coil springs were used for retraction of the canines on both sides which was done on a 0.18 inch stainless steel wire. The casts obtained before retraction and following 2 months of retraction was scanned using a white light scanner and the measurements of these scanned data were analyzed using the Geomagic software.

From the results obtained in our study, it is prudent to conclude that LLLT significantly hastens orthodontic tooth movement in humans with a healthy response from periodontal tissues. The irradiation parameters and protocol used in this study were successful in accelerating the tooth movement.

Future efforts should be directed toward investigating the precise dosimetry required for therapeutic laser effects, in order to achieve standardization of treatment protocols. Further studies and more clinical trials are necessary to evaluate the effect of LLLT in decreasing the overall orthodontic treatment duration.

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